WATER POLLUTION MONITORING

VOLUME 1, ENVIRONMENTAL
MONOGRAPH SERIES

rank L. Cross Jr.

WATER POLLUTION MONITORING

VOLUME 1, ENVIRONMENTAL MONOGRAPH SERIES

Edited by Frank L. Cross, Jr.

a TECHNOMIC® publication
TECHNOMIC Publishing Co., Inc.
265 W. State St., Westport, Conn. 06880

WATER POLLUTION MONITORING

265 W. State St., Westport, CT 06880

a TECHNOMIC® publication

Printed in U.S.A.

Library of Congress Card No. 74-33841

ISBN-0-87762-180-2

EFFLUENT AND STREAM MONITORING

INTRODUCTION

The discussion of monitoring in this monograph is related to water systems. It is evident that, pollution abatement must be related to the total system including all of the interfaces (i.e., source, carrier and receptor). Water can be considered independently because it is the natural repository of most waste materials.

The physical size of large bodies of water (the seas, oceans, and larger lakes) have led man to the misconception that his activities were too small to have a significant impact on such bodies of water. The magnitude of the misconception is now evident. The Great Lakes in the United States show the impact of man's interface. Likewise, man's impact on the oceans can be detected by an evident gradation of lead through the depth of the ocean waters, where the source of the lead presumably is fumes from internal combustion engines.

Large bodies of water have a large degree of assimilation, but at the same time, the avenues for elimination are significantly limited. Therefore, such bodies of water integrate the accumulation of materials over a long period of time. The response to this accumulation may develop at a relatively slow rate. The route of elimination may progress slowly through deposition of insoluble materials and through adsorption, assimilation, and precipitation of certain soluble materials. Thus, large bodies of water can involve slow response, and thus, in the short-term view have a definite characteristic of irreversibility.

Responses which are slow and reflect long-term accumulations make it necessary to assure a safety margin in control and management of man's impact on large bodies of water.

The impact of man's activities on surface stream water quality has been evident and has received a significant level of attention.

Flowing surface streams are dynamic systems which have rapidly responded to pollution inputs or abatement procedures.

The flowing stream receives natural inputs through direct contact with air, with land which constitutes the channel, and with runoff from natural areas. Additionally, the stream receives contaminated runoff from man's agricultural activities and from the surfaces of urban areas. These inputs are relatively uncontrolled in that they are delivered by the flow established during natural rainfall.

Other man-produced inputs include those sources of industrial wastewaters and municipal wastewaters that are collected and delivered to the receiving stream. The condition of water quality in our surface streams is largely a man-produced problem. The correction of that problem will definitely entail the control of land pollution, air pollution and wastewater treatment.

Man's efforts must significantly be related to the elimination of pollution problems at the source, and monitoring will play a significant role in that effort.

Wastewater treatment processes either remove and concentrate contaminants, or change the contaminant to innocuous materials. A wastewater treatment facility must interface successfully with the total environment. To do so, any gases emitted must be of acceptable quality and character, and the same must be true of any solids discharged.

Monitoring, Surveillance and System Management are necessary for man to have adequate information to understand the impact of pollutants upon water systems and to develop corrective measures. Monitoring,

Figure 1. Flowing stream system [1].

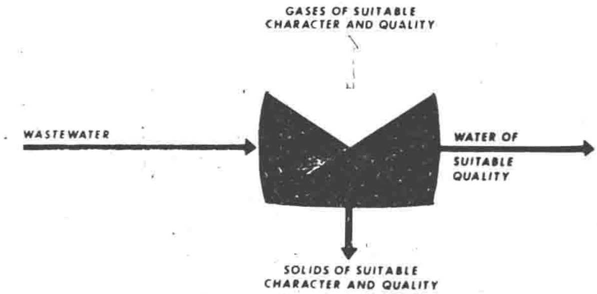


Figure 2. Pollution abatement facility [1].

which is defined as the collection of information on a continual basis, will provide this information.

Monitoring must provide information about the quality and characteristics of wastewater delivered to the system. It must then provide data for man to ascertain that the effluent objectives are being met by the treatment process and that other emissions for the system are suitable in character and quality. Monitoring information must be responsive to operating conditions and must be keyed to critical operating relationships.

For example, in the operation of an activated sludge system, removal efficiency is not the same for all types of materials. Therefore, process performance can effectively be based on the removal of a specific material which is critical to the water quality and found among those materials removed at lower kinetic rates. Also, in the operation of an ionic-exchange system, the objective might be to remove phosphate ion. The logical monitoring would be for phosphate ion, and monovalent ions such as chloride and nitrate might be permitted to pass through the system.

The quality of water in a flowing surface stream might be assured by adequate control of all inputs, but this approach might not be entirely practical or economically feasible. Some of the parameters that might be monitored in a flowing surface water stream are:

1. Low flow augmentation
2. Possible forms of in-stream treatment
3. Wastewater impoundment for controlled releases
4. Control of surface runoff and treatment
5. Variable operation of wastewater treatment facilities, etc.

Quality of water in the flowing stream is very frequently related to the discharge volume in the stream. During dry weather periods, the low volume of water available for dilution can result in undesirably high concentrations of certain pollution materials. Also, thermal pollution problems might relate directly to volume and temperature of water available. It might be economically practical to consider the installation of impoundments or of other facilities and/or techniques to provide low-flow augmentation.

There appears to be little potential for manipulative control strategies in large bodies of water. Therefore, the objective must be to monitor the water quality and provide the level of surveillance which can insure that objectives are being obtained so that proper objectives can be reached.

Thus far we have seen that:

1. Monitoring is basic to successful water quality control and management.
2. Operation of wastewater treatment facilities should utilize monitoring inputs as to quality, quantity and kinetics.
3. Time constants in treatment processes are normally short, therefore, monitoring information is required essentially instantly and definitely with delays of no longer than a few minutes.
4. Process control should be related to critical specific components rather than (or in combination with) gross parameters. Therefore, monitoring for specific organics or inorganic materials is indicated.
5. Flowing surface streams are potentially manageable, based on continual monitoring information. The system is responsive, provided that monitoring information is available within minutes, or at least within a few hours.
6. Large bodies of water are not readily manipulated to adjust the quality of water. However, monitoring is required for surveillance purposes.

STREAM AND WASTE GAUGING [2]

The initial step in developing a sound water quality control program is the metering, sampling, and analysis of all the significant streams leading into a plant, circulating through the plant, and leaving the plant. This procedure is basic to any of the following purposes:

1. To meet regulatory agency effluent requirements
2. To determine equitable charges for joint treatment
3. To design adequate treatment processes
4. To plan for water reuse and conservation
5. To determine produce losses, either for the purpose of planning a recovery system or for the design of processes which prevent such losses
6. To determine treatment efficiency and to trouble-shoot any process failures
7. To design treatment plant expansion
8. To serve as the basis for development of an automatic treatment system.

The importance of gauging and sampling in the conduct of a stream or waste survey cannot be over-emphasized. When one pauses to consider the cost of obtaining a sample or discharge measurement, it becomes readily apparent that equipment and techniques should receive careful consideration. If the analysis of survey data involves quantitative considerations, the accurate measurement of discharge assumes a level of importance equal to that of the laboratory and analytical results. (Flow X concentration X factor = pounds.) Similarly, the analytical results are only as representative as the sample upon which the analysis is performed. Success or failure in obtaining a repfesentative sample is dependent upon the adequacy of the equipment, and techniques employed in its collection.

In the following discussion, various sampling and gauging procedures are described which have been found to be applicable in field studies. In addition, an attempt has been made to provide information that will aid in the selection of equipment and methods.

GAUGING

A. Gauging Programs

Gauging stations are normally established at or near sampling stations in order to determine discharge concurrent with the collection of samples. The importance of accurate discharge measurements makes the careful establishment of gauging stations imperative. The time and effort involved in obtaining these measurements is a factor requiring that a minimum number of stations be established consistent with adequate definition of flow patterns.

B. Stream Gauging

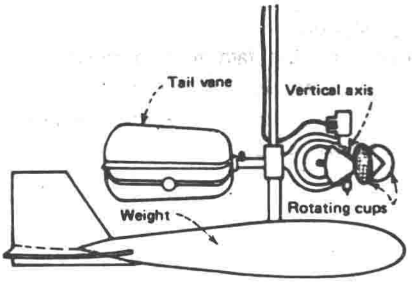
1. Current Meter.—The current meter is a device for measuring the velocity of a flowing body of water. The stream cross-section is divided into a number of sections, and the average velocity in each section is determined. The discharge is then found by summing the products of area and velocity of each section.

TABLE 1
Methods of Flow Measurement and Their Application to Various Types of Problems

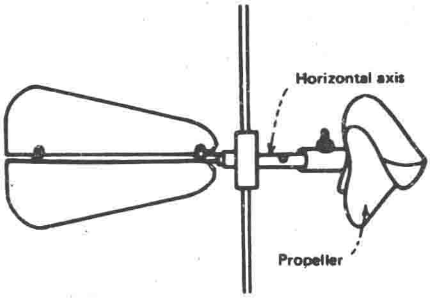
Device or Method	Flow Range Measurement	Cost	Ease of Installation*	Accuracy of Data	Application
Mathematical formulas	Small to large	Low	N/A	Fair	Open channels and pipe flow.
Water meters	Small to large	Low	Fair	Excellent	Pipe flow.
Bucket and stopwatch	Small	Low	N/A	Good	Small pipes with ends or where joints can be disconnected.
Pump capacity and operation	Small to large	Low	N/A	Good	Lines where water is being pumped.
Floating objects	Small to medium	Low	N/A	Fair	Open channels.
Dyes	Small to medium	Low	N/A	Fair to average	Pipe flow and open channels.
Salt dilution	Small to medium	Low	N/A	Fair	Pipe flow and open channels.
Orifice meter	Small to large	Medium	Fair	Excellent	Pipe flow.
Weirs and flow recorders	Small to large	Medium	Difficult	Good to excellent	Open channels.
Parshall Flume	Small to large	High	Difficult	Excellent	Open channels.
Venturi meter	Small to large	High	Fair	Excellent	Pipe flow.
Magnetic flow meter	Small to large	High	Fair	Excellent	Pipe flow.
Flow nozzles	Small to large	Medium	Fair	Excellent	Pipe flow.
Pitot tube	Small to medium	Medium	Fair	Good	Pipe flow.
Rotameter	Small to medium	Medium	Fair	Excellent	Pipe flow.

*N/A = Not Applicable

If the gauging station is properly chosen and a sufficient number of observations are made, a stage vs. discharge relationship may be determined. This method is recommended when the quantity of water to be measured is large and the available fall is small. It is also useful for measuring smaller discharges when it is impractical or uneconomical to employ such devices as a weir or flume.



Vertical axis current meter



Horizontal axis current meter

Figure 3. Current meters are made either with vertical axis (top) or horizontal axis (propeller type). [2]

2. Weirs.—A weir may be defined as a bulkhead across a channel, in the top of which is a notch through which liquid flows. This notch, of regular shape and dimensions, is called the weir notch, and its bottom edge is known as the crest. The sheet of liquid passing through the notch and falling over the weir crest is known as the nappe. The difference in elevation between the crest and the liquid surface at a point upstream, a specified distance from the bulkhead, is known as the head of the weir. Head discharge relationships have been developed for the several types of weirs.

Weirs are especially adapted to situations where a continuous or semi-continuous discharge record is desired. The principal disadvantages of the weir are the labor required in installation, and the fact that, if the water is high in solids, siltation in the weir pond may destroy its usefulness.

(a) Standard Contracted Rectangular Weir.—This type of weir has its crest and sides so far removed from the bottom and sides of the channel that full contraction of the nappe is developed.

(b) Standard Suppressed Rectangular Weir.—This type of weir has its crest so far removed from the bottom of the channel that full crest contraction is developed. The sides of the weir are coincident with the sides of the channel so that no lateral contraction of the nappe is possible.

(c) V-Notch Weirs.—In this type of weir, the notch is in the shape of a "V" with the sides of the notch being inclined equally from the vertical. The north angle may be of almost any magnitude, but is usually either 60° or 90°. This type of weir is especially suited to the accurate measurement of small discharges since more head is developed than for the same discharge with a rectangular weir. It is to be preferred for discharges less than 1 cfs and is at least as accurate as any other type of weir for discharges up to 10 cfs.

(d) Submerged Weirs.—If it is impossible to use one of the above weirs (because of insufficient available fall, for example), a submerged weir may be employed. This is essentially a standard suppressed rectangular weir in which the water surface downstream is above the crest level.

There are certain conditions of installation and operation which must be satisfied if weir measurements are to be accurate. Most hydraulic handbooks and textbooks provide this information along with discharge formulas and tables for the several types of weirs. Frequent errors in weir installation include failure to provide proper ventilation of the nappe and insufficient attention to horizontal and vertical installation. It is essential that the installation of the weir comply with recommended procedures if results are to be reliable.

3. Parshall Flume.—The Parshall flume is an open constricted channel in which differences in elevation of the liquid flowing through are translated into rate of flow. It consists of an entrance section with converging vertical walls and level floor, a throat section with parallel walls and floor declining downstream, and an exit section with diverging vertical walls and floor inclining downstream. The Parshall flume is especially adapted to situations where a continuous or semi-con-

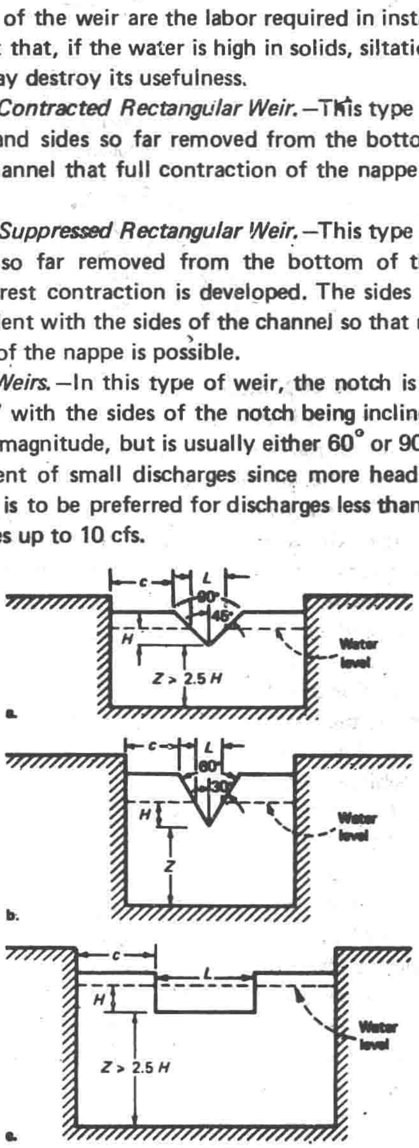


Figure 4. Weirs, 60- and 90-deg. V-notch and rectangular. [2]

tinuous discharge record is desired. Its most significant advantages are low head requirements, very little effect from approach velocity, dependable accuracy, wide variations in capacity, and the fact that, because it is self-cleaning, its usefulness will not be impaired by water high in solids. The primary disadvantage is the cost of installation, which may be significantly higher than for weirs. This high installation cost is occasioned, at least in part, by the precision required if accurate discharge measurements are to be expected.

C. Gauging Conduits and Open Channels

1. Weirs and Parshall Flumes.—Weirs and Parshall flumes are very well adapted to gauging conduits and open channels.

TABLE 2

Measuring Technique	Type of Monitoring Effluent	 Stream
Weirs and Parshall flumes	X	X
Bucket and Stopwatch	X	—
Velocity Area Methods		
Current meter	—	X
Floats	X	X
Dye	X	X
Depth Slope	X	—
Open End Pipe Flow	X	—
Head Measuring Devices	X	X

2. Bucket and Stopwatch.—In this method, the time required to fill a container of known volume is measured. This is then translated into a rate of flow. This method should be confined to the measurement of small discharges. A modification of it involves the use of a tank in the process which carries the full flow to be measured. The liquid level in the tank may be dropped a known amount and the time required to refill the tank measured. Knowing the volume of the portion of the tank that was refilled, the rate of flow may be computed. Unless the volume of the container to be filled is such that at least 20 sec are required for filling, the accuracy of this method is very questionable.

3. Velocity-Area Methods.—These methods of discharge measurement involve the determination of the velocity and the cross-sectional area of the flowing liquid. The discharge is then computed as the product of velocity and area.

(a) Current Meter.—The current meter may be employed in the same manner as in stream gauging. However, the presence of foreign materials such as rags, fibers, or slimes may reduce the accuracy of velocity readings. Also, corrosive waters may damage the meter. If the depth of flow is slight, it may be difficult, if not impossible, to use a current meter.

(b) Floats.—Floats may be used to estimate the time of travel between two points a known distance apart. The velocity so obtained may be multiplied by 0.85 to give the average velocity in the vertical. Knowing the mean velocity and the area of the flowing stream, the discharge may be estimated. Floats should be employed only when other methods are impractical.

(c) Dye.—A rough estimate of velocity of flow may be obtained by injecting dye into the flowing stream and timing its travel between two points a known distance apart. Discharge may then be estimated if the area of the flowing stream is known.

(d) Depth-Slope.—If the depth of the flowing stream and the slope of the sewer invert are known, the discharge may be computed by means of any one of several pipe flow formulas.

4. Open End Pipe Flow.—The following methods can be employed when other more precise means are not practical. They can be employed, however, only when there is free discharge to the air.

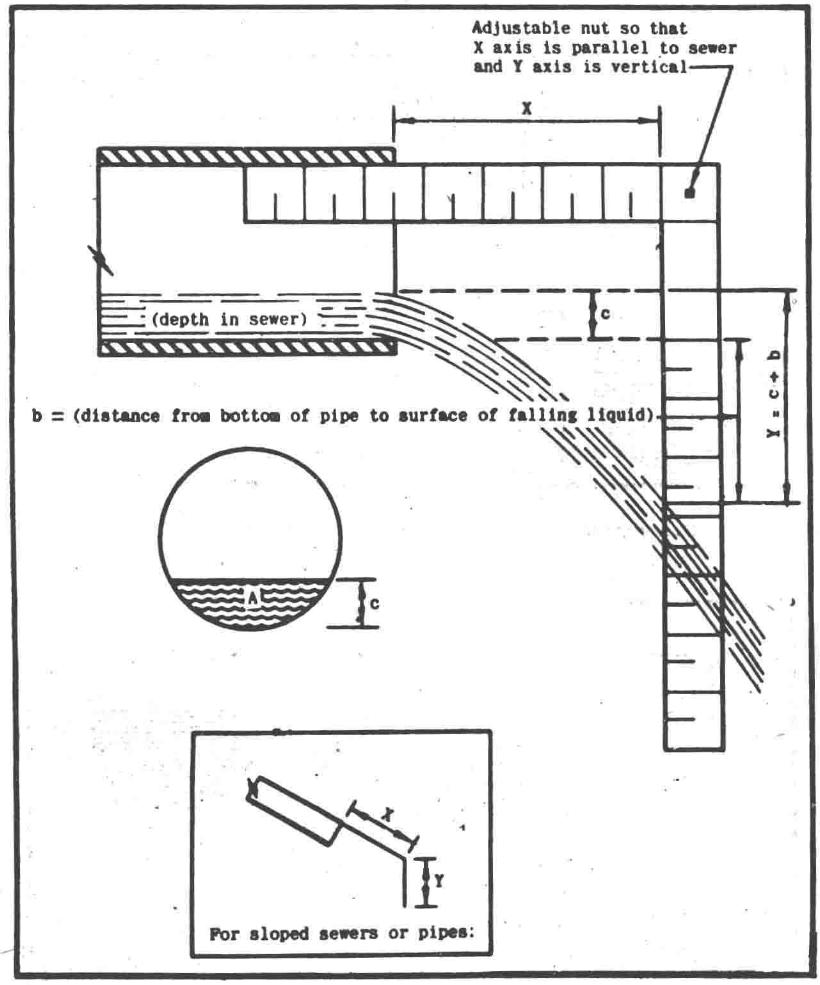


Figure 5. Open-pipe flow measurement — this device, adjusted to the slope of a sewer and calibrated, can then be clamped to the sewer outfall.

(a) Coordinate Method.—Discharge may be computed by the following formula:

$$Q\ (\text{gpm}) = \frac{1800\ AX}{Y}$$

where: A = cross-sectional area of liquid in the pipe (sq ft)
X = distance between the end of the pipe and the vertical gauge in ft, measured parallel to the pipe
Y = vertical distance from water surface at the end of the pipe to the intersection of the water surface with the vertical gauge, in ft

(b) California Pipe Flow Method.—This method may be used only for horizontal pipes having free discharge. If the pipe is not horizontal, a connection must be made to one that is. The horizontal length must be not less than 6 times the diameter of the pipe. Discharge may be computed by the following formula:

Q (gpm) + $T \times W$
where $T = 3{,}900\ (1 - \frac{a}{d})\ 1.88$
$D = d^{2.48}$

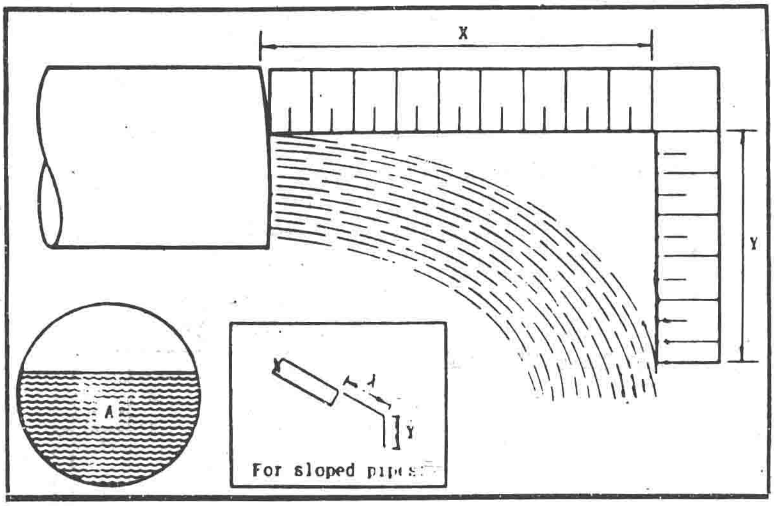


Figure 6. Open-pipe flow measurement requires two dimensions that locate the surface of stream after it leaves the pipe.

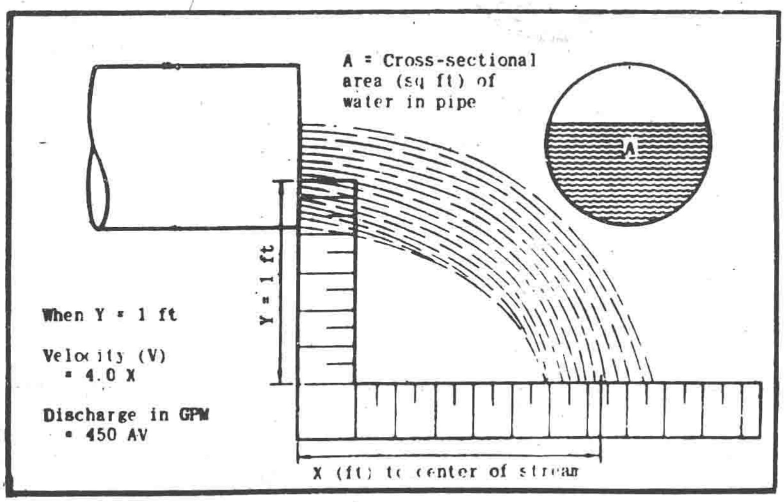
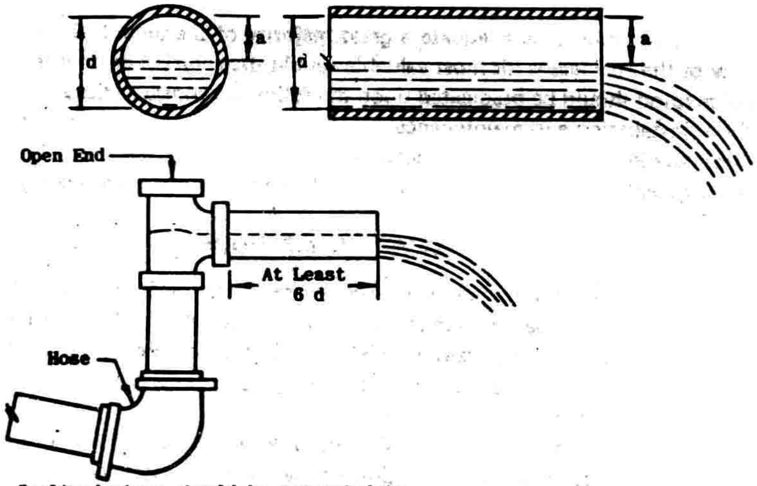


Figure 7. How to measure velocity and discharge from a pipe.

5. Dilution.—Flow may be measured by adding to the flow to be measured a solution containing a known concentration of some chemical. This solution must be added at a constant known rate. The concentration of the chemical at some point downstream is measured after adequate mixing has taken place. If the natural concentration of the chemical in the waste stream is known, the discharge may be computed. Salt is most commonly used for this purpose, but any chemical easily identified and not subject to reaction in the waste stream may be used. The rate of addition of the solution must be negligible compared to the discharge to be measured. Assuming that the rate of addition has no effect on the total discharge, the computation to be made is as follows:

$$Q_1 = \frac{Q_2 C_2}{C_2 C_1}$$



Inclined pipes should be connected to a horizontal length of pipe by hose.

Figure 8. Measurements needed for California Pipe Flow Method.

where: Q_1 = Discharge of waste stream
Q_2 = Rate of addition of solution
C_1 = Concentration in waste stream above point of addition
C_2 = Concentration in solution added
C_3 = Concentration in waste stream below point of addition

D. Head Measuring Devices

Several of the above gauging methods require the measurement of water level in order that discharge may be determined. Any device used for this purpose must be referenced to some zero elevation. For example, the zero elevation for weir measurements is the elevation of the weir crest. The choice of method is dependent upon the degree of accuracy and the type of record desired.

1. Hook Gauge.—The hook gauge measures water elevation from a fixed point. The hook is dropped below the water surface and then raised until the point of the hook just breaks the surface. This method probably will give the most precise results when properly applied.

2. Staff Gauge.—The staff gauge is merely a graduated scale placed in the water so that elevation may be read directly.

3. Plumb Line.—This method involves measurement of the distance from a fixed reference point to the water surface by dropping a plumb line until it just touches the water surface.

4. Water Level Recorder.—This instrument is used when a continuous record of water level is desired. A float and counterweight are connected by a steel tape which passes over a pulley. The float should be placed in a stilling well. A change in water level causes the pulley to rotate which, through a gearing system, moves a pen. The pen traces water level on a chart which is attached to a drum that is rotated by a clock mechanism. When properly installed and maintained, the water level recorder will provide an accurate, continuous record.

E. General Considerations

This discussion has been limited to those methods of flow measurement that have been found to be most consistent with the requirements of field studies. Measurement of flow in pipes under pressure has been omitted since measurements of this type are seldom required in the course of a short term field study. Similarly, many acceptable methods of measuring free surface flow have been omitted in the belief that the methods discussed herein should be adequate a great majority of the time. It should be emphasized, however, that the ingenuity of the engineer is his most valuable tool in the solution of unusual problems.

The choice of method should be predicated upon the following considerations:

1. Ease and cost of installation and maintenance
2. Obtainable accuracy in relation to desired accuracy
3. Adequacy (e.g., water level recorder should be used if a continuous record is desired).

SAMPLING METHODS

The basis for any plant pollution abatement program rests upon information obtained by sampling. Thus, all subsequent decisions may be based upon incorrect information if this step is not accurately pursued. There are several pitfalls which can occur if sampling is performed in a careless or naive manner. If a few basic principles are followed and if those responsible for sampling are forewarned, reliable results can be obtained without extensive and costly resampling.

Obtaining good results will depend upon certain details. Among these are the following:

1. Insuring that the sample taken is truly representative of the wastestream,
2. Using proper sampling techniques,
3. Protecting the samples until they are analyzed.

Obviously, the type of sample and sampling equipment will depend upon:

A. Pollutants to be monitored
B. Quantity of sample required
C. Frequency of sampling
D. Character of liquid (fluid) being sampled
E. Nature of the sampling station

TABLE 3

Volume of Sample Required for Determination of the Various Constituents of Industrial Water [2]

	Volume of Sample,[a] ml
PHYSICAL TESTS	
*Color and Odor	100 to 500
*Corrosivity	flowing sample
*Electrical conductivity	100
*pH, electrometric	100
Radioactivity	100 to 1000
*Specific gravity	100
*Temperature	flowing sample
*Toxicity	1000 to 20 000
*Turbidity	100 to 1000
CHEMICAL TESTS	
Dissolved Gases:	
†Ammonia, NH_3	500
†Carbon dioxide, free CO_2	200
†Chlorine, free Cl_2	200
†Hydrogen, H_2	1000
†Hydrogen sulfide, H_2S	500
†Oxygen, O_2	500 to 1000
†Sulfur dioxide, free SO_2	100
Miscellaneous:	
Acidity and alkalinity	100
Bacteria, iron	500
Bacteria, sulfate-reducing	100
Biochemical oxygen demand	100 to 500
Carbon dioxide, total CO_2 (including CO_3^{-}, HCO_3^{-}, and free)	200
Chemical oxygen demand (dichromate)	50 to 100
Chlorine requirement	2000 to 4000
Chlorine, total residual Cl_2 (including OCl^{-}, HOCl, NH_2Cl, $NHCl_2$, and free)	200
Chloroform - extractable matter	1000
Detergents	100 to 200
Hardness	50 to 100
Hydrazine	50 to 100
Microorganisms	100 to 200
Volatile and filming amines	500 to 1000
Oily matter	3000 to 5000
Organic nitrogen	500 to 1000
Phenolic compounds	800 to 4000

(continued)

TABLE 3
(Continued)

Miscellaneous:	**Volume of Sample,[a] ml**	*Cotions:*	**Volume of Sample,[a] ml**
pH, colorimetric	10 to 20	Nickel, Ni^{++}	100 to 1000
Polyphosphates	100 to 200	Silver, Ag^{+}	100 to 1000
Silica	50 to 1000	Sodium, Na^{+}	100 to 1000
~~Solids~~, dissolved	100 to 20 000	Strontium, Sr^{++}	100 to 1000
Solids, suspended	50 to 1000	Tin, Sn^{++} and Sn^{++++}	100 to 1000
Tannin and lignin	100 to 200	Zinc, Zn^{++}	100 to 1000
Cotions:		*Anions:*	
Aluminum, Al^{+++}	100 to 1000	Bicarbonate, HCO_3^-	100 to 200
†Ammonium, NH_4^+	500	Bromide, Br^-	100
Antimony, Sb^{+++} to Sb^{+++++}	100 to 1000	Carbonate, CO_3^{--}	100 to 200
Arsenic, As^{+++} to As^{+++++}	100 to 1000	Chloride, Cl^-	25 to 100
Barium, Ba^{++}	100 to 1000	Cyanide, Cn^-	25 to 100
Cadmium, Cd^{++}	100 to 1000	Fluoride, Fl^-	200
Calcium, Ca^{++}	100 to 1000	Hydroxide, OH^-	50 to 100
Chromium, Cr^{+++} to Cr^{++++++}	100 to 1000	Iodide, I^-	100
Copper, Cu^{++}	200 to 4000	Nitrate, NO_3^-	10 to 100
†Iron, Fe^{++} and Fe^{+++}	100 to 1000	Nitrite, NO_2^-	150 to 100
Lead, Pb^{++}	100 to 4000	Phosphate, ortho, PO_4^{---}, HPO_4^{--}, $H_2PO_4^-$	50 to 100
Magnesium, Mg^{++}	100 to 1000	Sulfate, SO_4^{--}, HSO_4^-	100 to 1000
Manganese, Mn^{++} to $Mn^{+++++++}$	100 to 1000	Sulfide, S^{--}, HS^-	100 to 500
Mercury, Hg^{+} and Hg^{++}	100 to 1000	Sulfite, SO_3^{--}, HSO_3^-	50 to 100
Potassium, K^{+}	100 to 1000		

[a] Volumes specified in this table should be considered as a guide for the approximate quantity of sample necessary for the particular analysis. The exact quantity used should be consistent with the volume prescribed in the standard method of analysis, whenever the volume is specified.

* Aliquot may be used for other determinations.

† Samples for unstable constituents must be obtained in separate containers, preserved as prescribed, completely filled and sealed against all exposure.

There are six major types of sampling techniques: individual or grab sample, simple composite, sequential composite, continuous sample, hand proportioned composite, and automatically proportioned composite. *The individual or grab sample* is retained as a separate entity in its own container. In the extreme case, for very small flows, the entire stream can be collected during the time interval selected, then mixed, and an aliquot taken for analysis.

The simple composite requires that all samples taken over the specified time interval be deposited in a single container. If, however, the composite is to be analysed for oily materials, it must be divided between two separate containers. This is true also if different methods of preservation are required (other than refrigeration) for the proposed analyses.

The sequential composite requires the collection of a series (usually 2 to 8) of individual samples per container, each container representing a specific time period, generally one hour. Such a procedure is particularly useful where the character of the waste may vary significantly from hour to hour, where batch dumping is expected, or where self-cancelling conditions occur, such as alternating high and low pH, which would not be apparent in a simple composite sample.

The continuous sample in which a small amount of sample is collected in continuous flow is useful for feeding monitors or pilot scale processes, or for sampling receiving waters. This technique is not recommended where the stream is high in suspended solids unless special provisions are made to avoid settling and plugging or partial plugging of the lines. If the continuous sample is composited over a long period of time, the product is large, at times too large to be conveniently handled.

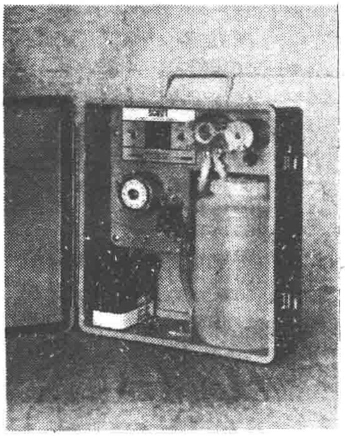


Figure 9. Simple composite sampling unit.
Source: N-CON Systems Co., Inc.
New Rochelle, NY

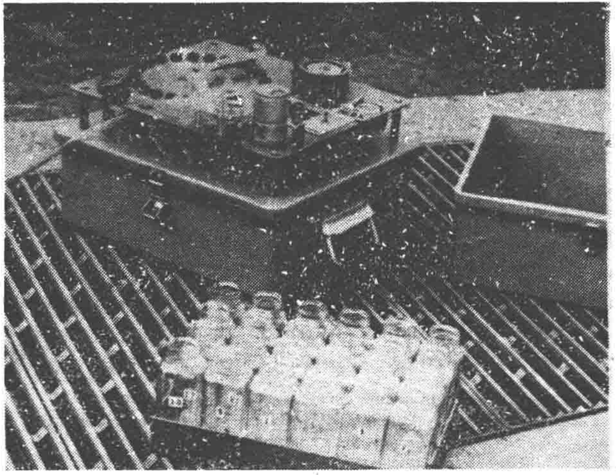


Figure 10. Sequential composite sampling unit.
Source: N-CON Systems Co., Inc. – New Rochelle, NY

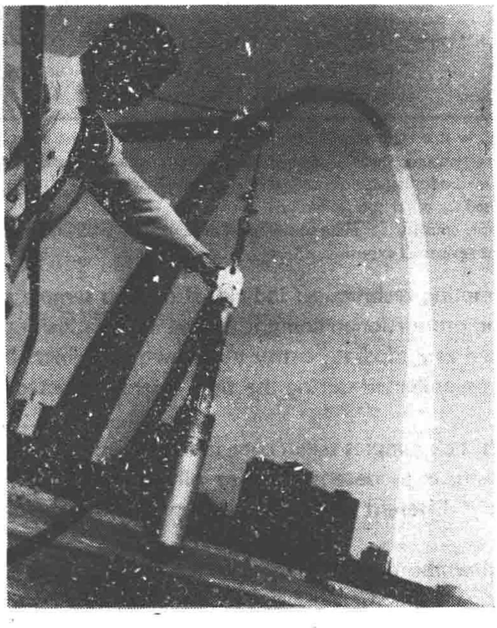


Figure 11. Pump supplies a continuous sample to sensors.
Source: Honeywell Industrial Division
1100 Virginia Drive
Fort Washington, Pennsylvania 19034

The hand proportioned composite can be obtained where flow charts are available. Individual or sequential composite samples are manually composited in proportion to the flow to obtain this useful and representative type of sample.

The automatically proportioned composite does require additional equipment and an understanding of the principles of proportioning, but is not especially complicated. Sampling in proportion to flow may be accomplished in either of two ways: By varying the frequency of sampling in direct ratio to flow (VcTv, volume constant, time variable), or by varying the size of the individual aliquots in proportion to flow volume (VvTc, volume variable, time constant).

Samples should be analyzed as soon as possible after collection. However, in practice, immediate analysis is seldom feasible. Cognizance should be taken of certain time-dependent chemical changes that can occur in samples, such as:

1. Metal cations may precipitate as hydroxides or form complexes.
2. The valence state of the ions may change by oxidation or reduction.
3. Metal cations may be adsorbed on the surfaces of glass, plastic, or quartz containers.

Microbiological activity may also change the characteristics of the sample as follows:

1. Cell lysis may increase the BOD and COD.
2. Cell productivity may change the BOD and COD.
3. The organic nitrogen and organic phosphorus content may be changed.

TABLE 4

Suggested Sampling or Compositing Schedule [3]

Characteristic	High Variability	Low Variability
BOD[a]	4 hr	12 hr
COD or TOC[a]	2 hr	8 hr
Suspended Solids	8 hr	24 hr
Alkalinity or Acidity	1 hr grab	8 hr grab
pH	Continuous	4 hr grab
Nitrogen and Phosphorus[b]	24 hr	24 hr
Heavy Metals	4 hr	24 hr

[a] The compositing schedule where continuous samplers are not used depends on variability, i.e., 15 min for high variability to 1 hr for low variability.

[b] Does not apply to nitrogen or phosphorus wastes (e.g., fertilizer).

In a water quality management program, automatic monitoring of several water characteristics has proven to be a dependable method of control. In wastewater treatment, numerous parameters are used for operational control; however, the number of parameters that can be automatically measured without difficulty are limited.

Sensors for automatic monitoring of wastewaters are especially sensitive to the presence of interferences. Thus, great care should be exercised in the selection of automatic equipment in order to ensure that it will function satisfactorily in the wastewater to be monitored.

Automatic monitoring has the following advantages [3, 4]:

1. The parameters of interest are recorded on a continuous basis and a clear picture is obtained of the variation of the recorded parameters with time. It should be noted, however, that continuous flow measurement data must also be available in order to calculate the total amount of pollutants flowing on a daily basis.
2. There is a shorter time lag between sampling and analysis than in manual sampling. In addition, problems resulting from storage of samples are eliminated.
3. Automatic monitoring systems can be combined with an alarm system that will give advance warning when a high concentration of an undesirable parameter occurs. For example, an automatic conductivity measurement instrument could be set to detect high values. When this occurs a by-pass valve

TABLE 5

Sample Preservation [3]

Parameter	Preservative	Maximum Holding Period
Acidity-Alkalinity	Refrigeration at 4° C	24 hours
Biochemical Oxygen Demand	Refrigeration at 4° C	6 hours
Calcium	None required	7 days
Chemical Oxygen Demand	2 ml H_2SO_4 per liter	7 days
Chloride	None required	7 days
Color	Refrigeration at 4° C	24 hours
Cyanide	NaOH to pH 10	24 hours
Dissolved Oxygen	Determine on site	No holding
Fluoride	None required	7 days
Hardness	None required	7 days
Metals, Total	5 ml HNO_3 per liter	6 months
Metals, Dissolved	Filtrate: 3 ml 1:1 HNO_3 per liter	6 months
Nitrogen, Ammonia	40 mg $HgCl_2$* per liter - 4° C	7 days
Nitrogen, Kjedahl	40 mg $HgCl_2$* per liter - 4° C	Unstable
Nitrogen, Nitrate-Nitrite	40 mg $HgCl_2$* per liter - 4° C	7 days
Oil and Grease	2 ml H_2SO_4 per liter - 4° C	24 days
Organic Carbon	2 ml H_2SO_4 per liter (pH 2)	7 days
pH	Determine on-site	No holding
Phenolics	1.0 g $CuSO_4$/1 + H_3PO_4 to pH 4.0 - 4° C	24 hours
Phosphorous	40 mg $HgCl_2$* per liter - 4° C	7 days
Solids	None available	7 days
Specific Conductance	None required	7 days
Sulfate	Refrigeration at 4° C	7 days
Sulfide	2 ml Zn acetate per liter	7 days
Threshold Odor	Refrigeration at 4° C	7 days
Turbidity	None Available	7 days

could be opened and the waste stream directed to a storage basin from which it could be gradually added into the waste treatment system.

4. Instrumentation, professionally installed, properly maintained to insure good operating order provides extreme precision of operation and optimum utilization of manpower and facilities. For example, the time lag encountered for an operator to get to a remote station to make a change is eliminated . . . all system adjustments can be effected immediately when and where needed from a centralized location.
5. The value of indication and the recording of key system data cannot be discounted lightly. When this information is received at a central operating point in the facility, the operator knows exactly what is happening at that time at each of various control points in the system. Thus, not only can operating conditions be effectively analyzed but also this information can be invaluable for planning future operations.
6. A complex, multi-unit system can be operated with fewer personnel. Continuous, reliable measurements of key variables such as flow, level, and pressures in pump control and distribution systems reduce pumps, piping and storage to the level of present need.
7. Reduced mileage in automotive service units necessary for maintenance crews over a year's time period can accomplish material savings in operating costs. Operation can be maintained and continued at times when remote stations may be inaccessible due to flooding, inclement weather, etc.
8. Continuous water quality monitoring and control of specific parameters (hardness, turbidity, chlorine residual) results in higher efficiency by increasing thru-put rates at higher quality levels. Modern instrumentation has made a significant contribution towards permitting design and treatment operations to accommodate loading rates at more than double the traditionally established values of the past.