

## CHAPTER 10

# Joint Treatment of Raw Industrial Waste with Domestic Sewage

### Introduction

Industrial-waste problems should be solved using systems engineering, which when applied to industrial wastes implies combining the artful and scientific factors toward optimum solutions to treatment problems. When an engineer considers only the scientific or art factors involved in any waste-treatment problem, the solution is less than ideal. The more informed engineer uses as much of both art and science as possible in solving these problems. Even so, the result may be less than an optimum solution because of the interdependencies of many factors. Today's enlightened and progressive waste-treatment engineer takes both social and physical factors into consideration.

These factors can usually be applied to the major question of "which path to follow." As seen in Figure 10.1, industry must decide whether to treat its own waste or to contract with the municipality to accept, treat, and dispose of its wastes. Twelve potential combinations of alternatives, or side paths, are also available to an industrial plant. For example, an industrial plant may decide to partially treat its waste (alternatives 2, 4, 7, or 10) and then deliver the residual-waste volume and load to the municipal treatment plant for final treatment and disposal. It is vital then to point out and discuss the many factors of both types that will assist us in selecting the correct alternative path to follow, and hence the overall solution to these problems.

Before examining the factors that affect joint treatment decisions, the following four rules are useful in selecting an alternative.

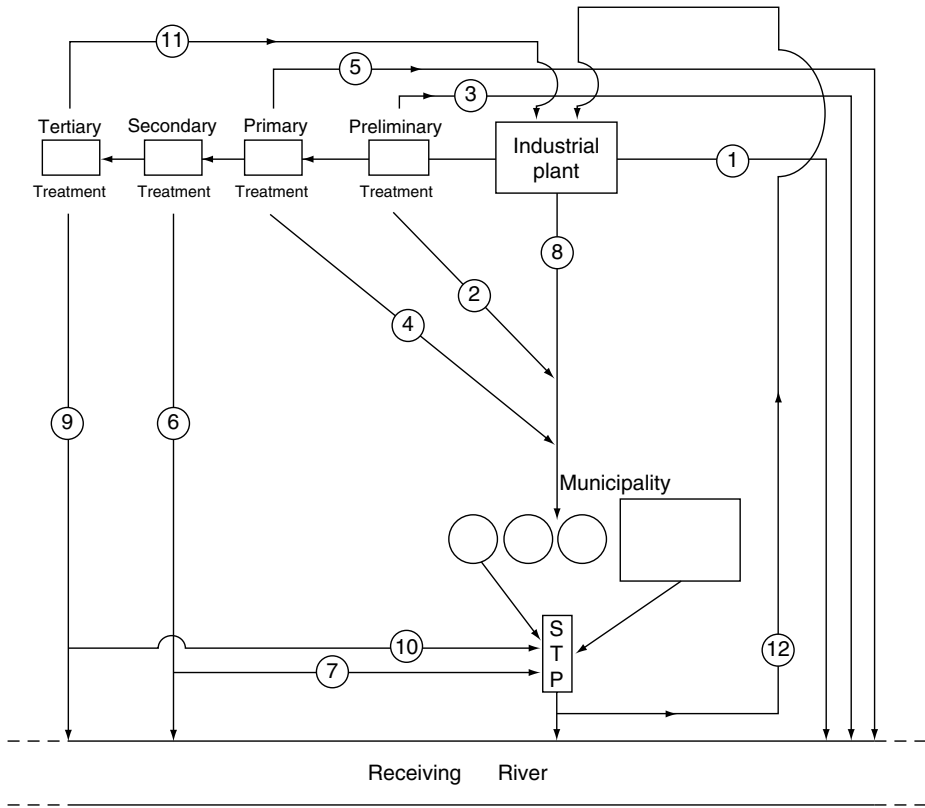


FIGURE 10.1. Twelve alternatives of industrial-waste treatment systems.

	<i>Industry</i>	<i>Municipality</i>
(1) Objective	To produce the best product at least cost	To provide best living conditions for people at lowest cost
(2) Conflict	Production causes increased municipal costs (air, water, and land environmental protection)	People depend upon industry for work and money, but it destroys the environment at the same time
(3) Solution	Produce goods in amounts and types so as to minimize adverse environmental impact	Only purchase goods that are produced and sold economically and that do not cause environmental degradation
(4) Procedure	Select lowest-cost alternative that protects the environment	Inform people of the environmental costs of production and adverse environmental impacts

Elements of the art and science involved in determining the optimal alternative are listed below:

- A. Art in industrial wastes
  - 1. Precedent
  - 2. Social relationship of industry and municipal officials
  - 3. Political compatibility of industry and municipality
  - 4. Sewer service charge
  - 5. Location of industry, especially in relation to municipal plant and receiving stream
  - 6. Competence of municipal plant operator
  - 7. Permanence of industrial production
- B. Science in industrial wastes
  - 1. Type of municipal sewage treatment
  - 2. Character of industrial waste
  - 3. Required water quality of receiving stream
  - 4. Volume of industrial waste in relation to that of municipality
  - 5. Economics of alternatives

In the following, I will consider the art or social factors first, because they have been less publicized and are perhaps less well known and understood by engineers.

## Art in Industrial Wastes

### *Precedent*

People are most inclined and even biased towards that which they are most familiar with or that which has been done rather uniformly and continuously in the past. There is a form of security in knowing that what is being suggested is in keeping with past practice and that its effects have been previously experienced. If, in the past, the practice has been to include all types of industrial waste regardless of volume or character in the municipal treatment system, this practice may be expected to be repeated. On the other hand, if separate treatment of industrial waste and municipal sewage has been encouraged, it will be difficult to change. Any change in policy will require considerable effort, education, and enthusiasm of all parties concerned. The engineer must recognize that, even with proper theoretical justification, it may be impossible to overcome and alter that which has become practice by precedent.

### *Social Relationship of Industry and Municipal Officials*

The consulting engineer must be aware of and appraise the social state of the relationship between the appropriate members of the industrial and municipal community. For one reason or another, this relationship may have been enhanced by a previous event that makes future compatibility for joint treatment possible. Likewise, some past experience, sometimes minor or seemingly insignificant, may have negatively affected the relationship and made future negotiations for joint treatment rather difficult. A designing engineer must develop the art of detecting and evaluating this compatibility at the onset of project planning. An oversight at this stage or even an inappropriate consideration or evaluation can be disastrous in terms of the search for an overall optimum path of solution to the joint problems.

### *Political Compatibility of Industry and Municipality*

When plant managers and major municipal officials share political outlooks, leaning, cooperative solutions to waste treatment are facilitated. The engineer must determine this relationship and consider the likelihood of a change in municipal officials in an election year during the progress of the project.

### *Sewer Service Charge*

Municipalities are composed of elected officials, each possessing a philosophy on the subject of patronage or subsidy for local industry. Some prefer to accept all wastes at a minimum charge or flat fee, or on a water-use basis. Others believe that industry should solve its own environmental problems, and should it want to have the municipality treat its waste, it should be ready and willing to pay a sewer service charge that correctly and adequately covers capital and operating costs. The engineer should ascertain which type of feeling prevails in the municipality prior to establishment of such changes. Industry usually does not object to a reasonable charge but often objects to the philosophy of a comprehensive, complicated, or involved charge that may lead to many unnecessary confrontations. It might prefer to treat its own waste, regardless of "on-the-surface" economics, rather than face potential disagreements with public officials.

### *Location of Industry*

The location of the industrial plant relative to both municipal sewers and treatment facilities and the final receiving stream plays a vital part in influencing industry for or against combined treatment. At first consideration, one might presume that economics alone is affected by plant location. True, the cost of connecting to and transmitting through existing or potential municipal sewers for a given distance directly affects costs. However, accessibility to sewers and proximity to treatment plants and receiving streams is important from a psychological viewpoint as well. Questions such as "why have two treatment plants so close to each other?" or "why pump and maintain a private pumping station and connecting sewer systems when we can treat our own wastes and dispose of them by gravity nearby?" are difficult to answer only in terms of dollars. Proximity enhances joint solutions regardless of economic considerations.

### *Competence of Municipal Plant Operator*

The experience, congeniality, and prominence of supervisor and/or operator of a municipal treatment facility will enhance or hinder cooperative arrangements between industry and government. These qualities of the operating personnel are especially important in the initial stages of decision making. For example, industry usually considers combined treatment feasible and even desirable when the municipal operator is held in high esteem by associates on a state or national level. The basis for this feeling is deeply rooted from a psychological standpoint, but most probably stems from a feeling of security in knowing that the wastes will be treated in an optimally effective manner. An "easy-to-get-along-with" operator will enhance initial and continued discussions and negotiations. Combined treatment always manifests problems and difficulties of one type or another. Most can be solved with some effort, ingenuity, and cooperation. When

industry knows a priori that it is dealing with a person or people possessing these characteristics, combined treatment becomes practical. An experienced operator usually knows what plant operating changes to make during critical situations in order to avoid malfunctioning. This is reassuring to both industrial and municipal officials. Conversely, the lack of those operator characteristics demands greater consideration of separate industrial-waste treatment.

### *Permanence of Industrial Production*

Industry must show a profit for its owners in order to stay in business. The future of any given industrial facility depends primarily on the whims of consumers. When whims change, a given industrial plant has three alternatives: (1) reduce production, hopefully cutting costs so that net profits do not deteriorate; (2) change production to meet consumers preferences; and (3) cease all production to avoid deficit financing. In all three alternatives, the type or quantity of waste is altered considerably. Many industrial operations have found it necessary to resort to any or all of these alternatives over a 20- to 40-year period (during which time bonds for waste-treatment facilities are usually amortized). Industry has begun to recognize this as a fact of doing business.

Because technology is changing so rapidly and with it the needs and demands of customers, industry hesitates to enter into long-term contractual commitments, especially those concerned with waste-treatment facilities. Thus, industry is now recognized as being relatively impermanent when compared to municipal operations. Certain industries are more permanent or less apt to cease production entirely (as evidenced from past records only). For example, DuPont Chemical Corporation or U.S. Steel's main production facilities could be expected to continue operation—with some modifications—with greater assurance for longer periods into the future than a small leather tannery or a peach cannery. The former types of industries would be more likely to consider joint ownership of a treatment facility than the latter. The cannery or tannery would be inclined towards private ownership of its separate facilities. There are exceptions and even variations within the latter industries, mostly depending on the size and type of ownership of the industry, as well as specific past experiences that it may have had in waste-treatment problems.

Some of the more important scientific factors associated with joint industrial-waste treatment are discussed in the following section.

## Science in Industrial Wastes

### *Type of Municipal Sewage Treatment*

A secondary biological treatment plant, if adequately sized, can best be used to treat a readily decomposable organic-laden industrial waste. Typical examples include dairies, canneries, slaughterhouses, and tanneries. However, each of these wastes, as well as other typical organic wastes, contain contaminants that can interfere with effective treatment when combined with domestic sewage. For example, dairy wastes often turn to acid extremely fast and the lowered pH can affect biological oxidation. Many

canneries have an extremely alkaline lye-peel waste, which when discharged in slug loads can hamper biological oxidation. Slaughterhouse wastes contain slug loads of grease and blood that could hinder physical and biological processes. Tannery wastes contain chromium, sulfides, and lime, which are not compatible with normal sewage treatment. Proper pretreatment and plant operations, however, can remedy these problems. In some cases, it has been shown that trickling filters can handle industrial waste with fewer upsets than activated-sludge systems.

Little would be gained by either party if an industrial waste (such as from a dairy or textile mill) was treated in a municipal treatment plant consisting solely of primary treatment.

Industrial plant managers must make an assessment of the objectives of treatment required and then examine the municipal plant available or being planned. Mutually compatible objectives and treatment facilities would be conducive to combined treatment.

### *Characteristics of Industrial Waste*

When considering the treatment of wastes from a tissue-paper mill, industry needs a municipal plant that concentrates its equipment units on the removal of the finely divided suspended-solids area of waste treatment. It is of little benefit to the tissue-paper mill if the municipal plant possesses only a high-rate trickling filter primarily designed for biochemical oxygen demand (BOD) removal. Along similar lines, a metal-plating waste would not be a welcome addition to the high-rate trickling filter plant because of its potentially toxic metals and acids, as well as its lack of organic matter—hence, the need for BOD reduction.

The waste engineer must carry out a complete analysis of the industrial waste to ascertain its compatibility for treatment by various possible methods. Some analyses often overlooked by the traditional sanitary engineer include the  $k$ -value, the waste deoxygenation rate, ultimate oxygen demand, toxic chemicals and metals, temperature, grease content at reduced temperatures, refractory organic matter, phosphates and nitrates and other algae nutrients, and so on.

### *Receiving-Stream Water Quality*

It is a foregone conclusion that a stream which must be maintained in a high water-quality state requires maximum offshore waste treatment. Generally, this means a minimum of the equivalent to secondary treatment. But what is secondary treatment to an industry whose waste contains varied types of contaminants? Often the conventional biological treatment system will not adequately remove sufficient amounts of the contaminants. Sometimes specific treatment such as chemical precipitation followed by adsorption on activated carbon may remove more industrial contaminants than a secondary type of trickling-filter plant. Industry has inherited the moral, if not the legal, obligation of treating its waste in a manner so as to maintain the highest possible quality of water in the receiving stream. This cannot always be accomplished by following established state or federal rules. In many instances, ingenuity must be used and sacrifices must be made to remove the proper amount of specific contaminants. In one

specific waste problem, it was necessary for management to render a decision to completely eliminate one of its three raw materials. This particular raw material was relatively inexpensive, and thus a satisfactory product generated high profits. However, the waste resulting from using this particular raw material accounted for more than 80% of the total plant contamination. To remove the contamination by conventional treatment proved extremely costly, and after much deliberation, the industry reluctantly decided to discontinue use of the cheap raw material.

It is even more disconcerting for industry to be faced with a legal decision to install so-called *complete treatment* of its wastes when the receiving stream, even under critical conditions, shows little deterioration from the waste load. In this situation, industry should endeavor to prove to regulatory agencies its dilemma so that it can operate at optimum economic efficiency. The latter is essential for the long-term benefit of society, as long as valuable river resources are not degraded in the process.

#### *Volume Ratio of Industrial to Municipal Wastes*

A relatively small volume of industrial waste can usually be assimilated in a municipal sewage-treatment system regardless of its contaminants. Municipal plant operators generally react optimistically towards small volumes of any industrial wastes, agree to try to treat them, and end up accepting them with or without certain preconditions. If the ratio of waste volume to sewage had been greater, an attempt might never have been made to handle the waste, regardless of the potential of acceptability or treatability. Thus, when ratios are high, industry usually builds its own treatment plant despite the potentially favorable economics or the potential compatibility for joint treatment. There are exceptions to this generality, but they usually exist when a new facility is being contemplated by both municipal and industrial officials simultaneously.

#### *Economics of Alternatives*

Industry tends to select the least costly alternative, especially when other conditions are equal. How does industry select the least costly system? Usually industry prefers to compare alternative system costs on the basis of total capital expenditures. This method can often be misleading and even erroneous over the longterm. First, it does not take into consideration the annual cost of operation and maintenance required for effective treatment. Often, the least costly alternative can be the most expensive to maintain, especially when perfection is required in efficiency of operation.

Furthermore, the cost of obtaining loans for capital spending is not taken into account when considering only capital costs. This is significant during high-cost periods and when one or more alternatives entail public rather than private borrowing. It is well known that municipalities can usually borrow money at lower interest rates than private corporations.

And last, the financial rating of the borrower is a significant and often overlooked factor in comparing capital costs only. Certain public authorities may possess such poor financial ratings that many prominent profitable industrial firms may be able to borrow money as cheaply as or cheaper than the municipality.

Therefore, economic alternatives should be based on net annual costs, which include operation, maintenance, and amortization of capital costs. The latter should be selected on the realistic basis of the financial rating of the appropriate borrower, as well as on the basis of a reasonable bond amortization period, depending on the borrower's ability to repay and the expected life of the specific equipment required in each alternative.

The question of whether the optimum alternative selected is justified on any economic basis warrants consideration and up to now has been avoided by sanitary engineers. We have blindly presumed that what is required in the way of waste treatment by state or federal edict is required at any cost. This may be so, but the case can be strengthened by proper economic evaluation. We should compute the total net benefits to the surrounding immediate society of the specific waste-treatment alternative selected. Heretofore, we have lamented that these benefits were intangible and hence unmeasurable. (See Chapter 21 of this book for more information about benefits.)

Benefits that are affected by water quality include: (1) recreational use; (2) land use; (3) water withdrawal; (4) waste treatment; and (5) in-place water use.

### *Industrial Use of Municipal Sewage Plants*

It is often possible and advisable for an industry to discharge its waste directly to a municipal treatment plant, where a certain portion of the pollution can be removed (Nemerow 1951). A municipal sewage-treatment plant, if designed and operated properly, can handle almost any type and quantity of industrial waste (Hubbel 1935). Hence, one possibility that should be seriously considered is the cooperation of industry and municipalities in the joint construction and operation of a municipal wastewater treatment plant. There are many advantages to be gained from such a joint venture:

1. Responsibility is placed with one owner while the cooperative spirit between industry and municipality is increased, particularly if the cost sharing is mutually satisfactory.
2. Only one chief operator is required, whose sole obligation is the management of the treatment plant. The operator is not encumbered by the miscellaneous duties often given to the industrial employee in charge of waste disposal, and the chances of mismanagement and neglect that may result if industrial production people operate waste-treatment plants, are eliminated.
3. Since the operator of such a large treatment plant usually receives higher pay than separate domestic plant operators, better-trained people are available.
4. Even if identical equipment is required, construction costs are less for a single plant than for two or more. Furthermore, municipalities can apply for state and/or federal aid for plant construction, which private industry is not eligible to receive.
5. The land required for plant construction and for disposal of waste products is obtained more easily by the municipality.
6. Operating costs are lower because more waste is treated at a lower rate per unit of volume.
7. Possible cost advantages resulting from lower municipal financing costs, federal grants, and municipal operation can be passed on to the users and may permit

- higher degrees of treatment at a cost to each participant no greater than the cost for separate treatment at lower removal levels.
8. Some wastes may add valuable nutrients for biological activity to counteract other industrial wastes that are nutrient deficient. Thus, bacteria in the sewage are added to organic industrial wastes as seed material. These microorganisms are vital to biological treatment when the necessary BOD reduction exceeds approximately 70%. Similarly, acids from one industry may help neutralize alkaline waste from another industry.
  9. The treatment of all wastewater generated in the community in a municipal plant or plants enables the municipality to ensure a uniform level of treatment to all users of the river, and even to increase the degree of treatment given to all wastewater to the maximum level obtainable with technological advances.
  10. Acceptance of the joint treatment project and relinquishment of individual allocations would give the municipality full control of river resources and permit it to use the capacity of the river to the best advantage for the general public. The municipality has greater assurance of stream protection, because it has the opportunity for closer monitoring of effluent quality.
  11. Public relations are good for the municipality.
  12. Land is generally more available.
  13. No permit for discharge is needed except for a contractual agreement between the two parties.

Among the many problems arising from combined treatment, the most important is the character of the industrial wastewater reaching the disposal plant. Equalization and regulation of discharge of industrial wastes are sometimes necessary to prevent rapid change in the environmental conditions of the bacteria and other organisms that act as purifying agents, to ensure ample chemical dosage in coagulating basins, and to ensure adequate chlorination to kill harmful bacteria before the effluent is discharged to a stream.

Two factors in particular have focused on the subject of combined treatment for sewage and industrial wastes: increased interest in stream-pollution abatement, and the phenomenal growth of industry in the postwar years with the subsequent increase in demand for water.

Because most sewage plants use some form of biological treatment, it is essential for satisfactory operation that extremes in industrial waste characteristics be avoided and the waste mixture be (1) as homogeneous in composition and uniform in flow rate as possible and free from sudden dumpings (shock loads) of the more deleterious industrial wastes; (2) not highly loaded with suspended matter; (3) free of excessive acidity or alkalinity and not high in content of chemicals that precipitate on neutralization or oxidation; (4) practically free of antiseptic materials and toxic trace metals; (5) low in potential sources of high BOD, such as carbohydrates, sugar, starch, and cellulose; and (6) low in oil and grease content.

Combined municipal and industrial waste treatment is the most desirable arrangement, and at the same time, the most difficult to achieve. It is the author's contention that the difficulty is usually not a scientific one but one of human

compatibility and understanding. In numerous cases, the economics of the situation were overwhelmingly in favor of combined treatment and yet separate waste-treatment installations were finally used, primarily because of personality clashes and lack of sympathetic understanding.

What can municipalities do to assist industry in waste-treatment practices?

1. If the municipal treatment plant is new or being enlarged, it should be designed to serve the entire community, with all the existing and planned industry as members of a "corporation." Combined meetings, lectures, and actual visits to the treatment-plant site will enhance mutual understanding of the problems involved.
2. If the plant is already in operation, municipal officials should meet with industrial representatives and discuss the advantages and disadvantages of accepting industrial wastes into the system. Adequate safeguards such as a literature review, and pilot-plant experiments should precede administrative decisions, and any decision to accept the waste should be accompanied by a substantial and specifically detailed contract between the owner and user. Methods of sampling, analyses, charges, and waste characteristics should be clearly stated in this contract.
3. A municipality can purchase land, build a treatment plant for its industry, float bonds, and receive rent from industry for use of the plant and amortization of the bonds. In this way, the rental becomes an operating expense that industry can deduct from income *before* taxes rather than the long-term depreciation of capital assets involved in having its own plant. This feature is particularly attractive to industry.
4. Most important, perhaps, is the understanding that a municipality must have for its industry. All members of the city council should be in agreement that without industry, municipal survival is doubtful and its growth potential is nil. An industry located within the city limits is contributing taxes and intangible benefits to the city. Although it is common for new industry to locate outside city limits, where it can purchase sufficient land at a reasonable cost for future expansion, these industries, too, are an indirect but valuable addition to the community.
5. A municipality can design its treatment plant so that it will handle an industry's waste without pretreatment by the industry. An ideal arrangement is to take the industry into the business of waste disposal as a "member of the municipal corporation." Industry should pay for this service but not at the same rate as an individual householder, because a large contributor deserves concessions solely on the basis of lower unit costs for larger volumes. In addition, industry's intangible benefits to the community should be assessed and its share of the capital cost reduced proportionately.
6. Municipal controls of the influent from the industrial plant are costly and difficult to establish. Instead, it is recommended that industry control its own effluent so that the "corporation" disposal system operates efficiently. When, and if, the

system ceases to function as designed, a corporation meeting should be called to decide what measures should be taken to correct the situation. In this manner, the expenses of sampling and billing, as well as ill feelings caused by policing, are eliminated.

7. A good corporation will continually try to improve its efficiency of operation by conducting research on new methods of treatment. Research has been proven to pay off in the long haul and the lack of it has often led to plant and process obsolescence. Industry, with its research experience, could well lead the way in this connection by supporting continued research in specific combined treatment processes.
8. The designing environmental engineer should be selected by both the municipality and the industry for his or her competence and ability to work with equal ease with both groups. His or her fee should be on a lump-sum basis, approximating the sliding-scale percentage of estimated construction cost but not necessarily tied to this; rather than being penalized for reducing the capital costs (and, hence, his or her fees), he or she should be rewarded financially for economizing on construction and improving plant efficiency.

In summary, a municipality can assist its industry by encouraging mutual understanding, embarking on a program of education, and designing its plants to handle industrial waste. Other methods of assisting industry depend on the formation of a "corporation treatment plant" with joint responsibility for efficient operation. Municipal ownership and reduction in charges based on intangible and tangible industrial benefits should also be considered.

The Water Pollution Control Federation (WPCF) (1976) published a rather detailed (34 pages) pamphlet on all aspects of joint treatment. The reader is directed to this pamphlet for practical and economic aspects of this subject.

## Municipal Ordinances

Although there are many types of municipal ordinances, all are designed to place an upper limit on the concentration of various constituents in waste. Sometimes this upper limit is zero, because any quantity of a certain contaminant would be detrimental to the plant or its component parts. In addition to their obligation to abide by municipal ordinances, many industries enter into separate contracts with the city. Generally, such contracts include the obligation of the municipality to construct, operate, and maintain the treatment facilities and to finance the overall project by means of some type of bond; a declaration on the part of the industry as to the maximum quantity of flow, BOD, and solids; the percentage by volume of industrial waste as compared to municipal waste; the amount the industry will pay each year to cover operation and maintenance; provision for a penalty if stated limits are exceeded; and any other pertinent matters involving joint usage of the treatment system.

The following are dangers of inadequate sewer-use control (WPCF 1976): (1) explosion and fire hazards; (2) sewer clogging; (3) overloads of surface water (storm- or cooling-water pollution); (4) physical damage to sewers and structural damage to treatment plants; and (5) interference with sewage treatment.

A comprehensive sewer ordinance (Federation of Sewage and Industrial Wastes Association 1957) usually consists of the following principal parts: introduction; definition of terms; regulation requiring use of public sewers where available; regulations concerning private sewage and waste disposal where public sewers are not available; regulations and procedures regarding the construction of sewers and connections; regulations relating to quantities and character of waters and wastes admissible to public sewers; special regulations; provision for powers of inspectors; enforcement (penalty) clause; validity clause; and signatures.

Because industrial wastes vary so greatly in character, only broad limits can be established in any model ordinance, and ordinances should always be based on recommendations of the consulting engineer (Table 10.1). Most ordinances (Federation of Sewage and Industrial Wastes Association 1957) for the control of waste substances other than sanitary sewage act in the following ways:

1. They prohibit the discharge to the public sewers of flammable substances or materials that would obstruct the flow.
2. They state that industrial wastes will be admitted to the public sewers only by special permission of a stated municipal authority.
3. They ban all wastes that would damage or interfere with the operation of the sewage works, except when such wastes have been adequately pretreated, and even then their admission is to be at the discretion of a stated municipal authority.
4. They enumerate in detail, in a separate ordinance, the procedures outlined in no. 3.
5. They give detailed regulations to supplement the procedure in no. 3, stating specific limits for objectionable characteristics of industrial wastes.

A model ordinance (Federation of Sewage and Industrial Wastes Association 1957) may spell out in detail the following regulations relating to quantities and character of water and wastes admissible to public sewers:

*Section 1.* No storm water, roof runoff, cooling water, groundwater, etc., will be allowed in the sanitary sewer.

*Section 2.* Storm water or other uncontaminated drainage will be discharged to sewers that are designated combined or storm sewers only.

*Section 3.* No person shall discharge any of the following wastes to sanitary sewers except as hereinafter provided: (a) any liquid or vapor having a temperature higher than 150°F; (b) any waste containing more than 100 ppm by weight of grease; (c) any gasoline, etc., or other flammable or explosive liquid, solid, or gas; (d) any garbage that has not been properly ground; (e) any ashes, metals, cinders, rags, mud, straw, glass, feathers, tar, plastics, wood, chicken manure, or other interfering or obstructing solids; (f) any

TABLE 10.1  
Industrial Contaminants and General Limiting Values for Discharge into Municipal Sewerage Systems<sup>a</sup>

<i>Contaminant</i>	<i>Concentration Generally Limiting for Municipal Sewerage Systems</i>	<i>Reason for Limitation</i>	<i>If Contaminant Is Excessive, Acceptable Pretreatment Generally Required</i>
1. Flow	50% of municipal sewage flow	Causes sewage treatment system to react differently from its normal pattern as designed for municipal sewage. Unequalized or unproportioned industrial flow is especially troublesome	<ol style="list-style-type: none"> <li>1. Equalization and proportioning</li> <li>2. Recirculation and reuse within industry to reduce flow</li> <li>3. Redesign sewage treatment plant to react more specifically to industrial waste</li> </ol>
2. BOD 5,220°C	300 ppm	Exerts a disproportionately high percentage of oxygen-demanding organic matter to municipal wastewater	<ol style="list-style-type: none"> <li>1. Change in industrial manufacturing process</li> <li>2. Equalization</li> <li>3. Biological pretreatment plant</li> </ol>
3. Color	Visible in dilutions of 4 parts sewage to 1 part industrial waste	Color is normally not removed by domestic sewage treatment plants, will appear in the combined, treated effluent, will be readily detected and visually undesirable from an aesthetic standpoint	<ol style="list-style-type: none"> <li>1. Change in industrial manufacturing process</li> <li>2. Chemical pretreatment to remove color</li> <li>3. Equalization and/or proportioning</li> </ol>
4. Suspended solids	350 ppm	Overloads disproportionately normal domestic sewage treatment plants	<ol style="list-style-type: none"> <li>1. Change in industrial manufacturing process</li> <li>2. Equalization</li> <li>3. Sedimentation pretreatment plant</li> </ol>
5. pH	5.5–9	Corrosion of sewers and treatment plant equipment causes a diminution or malfunction of biological treatment units	<ol style="list-style-type: none"> <li>1. Equalization</li> <li>2. Neutralization</li> <li>3. Change in industrial manufacturing process</li> </ol>

TABLE 10.1 (continued)

<i>Contaminant</i>	<i>Concentration Generally Limiting for Municipal Sewerage Systems</i>	<i>Reason for Limitation</i>	<i>If Contaminant Is Excessive, Acceptable Pretreatment Generally Required</i>
6. Grease	100 ppm	Interferes with plant operating equipment—including aeration, primary sedimentation, etc. Overloads sludge-handling treatment units such as scum collection, digestion, and sludge-drying beds	1. Change in industrial manufacturing process 2. Install grease traps or remove pretreatment units
7. Heavy metals Cr, Sn, Pb, Zn, Hg, Cu, Ni, etc.	1 ppm Cu, Cr, 5 ppm Zn, N	Inhibits biological action in municipal sewage units, such as activated sludge, and trickling filters, and especially sludge digesters	1. Equalization 2. Chemical pretreatment and sedimentation pretreatment
8. Nonorganics and other toxic chemicals	None so as to be toxic to bacteria serving the treatment plant or people or animals working in or near the sewage plant	Exhibit toxicity towards biological treatment units and cause health hazard to people and animals	1. Change industrial plant process 2. Use of advanced pretreatment wastewater techniques
9. Inflammable liquids, foaming agents, rags, solidifiable greases, ashes, metals, cinders, mud, straw, glass, feathers, tar, plastics, wood, chicken manure, etc.	None in such quantities that will cause either a hazard to the environment or a nuisance to plant operation	Causes a nuisance and interferes with the normal operation of the domestic sewage-treatment plant	1. Removal by process change or physical means such as screening

10. Temperature	150°F	Hastens corrosion, drives out dissolved oxygen, volatilizes hazardous gases such as H <sub>2</sub> S	<ol style="list-style-type: none"> <li>1. Change in industrial process</li> <li>2. Use of cooling water systems</li> </ol>
11. Storm water	None resulting from direct connections or faulty sewer construction	Occupies valuable volume capacity of domestic and industrial sewers	<ol style="list-style-type: none"> <li>1. Construct separate sewer</li> <li>2. Use better construction procedures</li> </ol>
12. Refractory organic matter	None	Contaminates municipal sewage plant effluent for possible reuse downstream for water supplies	<ol style="list-style-type: none"> <li>1. Change in industrial manufacturing process</li> <li>2. Carbon adsorption pretreatment</li> </ol>
13. Refractory mineral matter	Boron 0.7 ppm NaCl 1000 ppm	Contaminates municipal sewage plant effluent for possible reuse for irrigation waters	<ol style="list-style-type: none"> <li>1. Change in industrial manufacturing process</li> <li>2. Pretreat industrial plant wastewater by membrane separation or distillation</li> </ol>

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<sup>a</sup>All industrial wastes can be treated in some manner at some cost with some relative effectiveness so as to render the contaminants suitably low in concentration or changed in character with the result that they may be discharged safely into the environment either directly or indirectly (through some municipal system). It is suggested that a literature survey be made of the effect of each contaminant at its expected level of concentration in the resulting domestic wastewater before acceptance or rejection of the industrial waste into any municipal system.

In cases where doubt exists about the effect of the industrial waste based upon personal experience or literature survey, laboratory and/or field prototype studies should be made to ascertain the precise effect on municipal sewage-plant systems. Pretreated effluents from industry can be examined in a similar manner.

The exact values of each contaminant are based on the best evidence available to the author, but exceptions can be found in each case. The user of this table must be prepared to render to it some flexibility in both allowable concentration and type of contaminants as more knowledge becomes available.

*Source:* Nemerow (1987).

wastes having a pH less than 5.5 or higher than 9.0 or having other corrosive effects; (g) any toxic wastes that may be hazard to sewage plant, persons, or receiving stream; (h) any suspended solids that the treatment of which at the sewage plant may involve unusual expenditures; and (i) any noxious gases.

*Section 4.* There shall be installations of interceptors for grease, oil, and sand when necessary.

*Section 5.* These installations shall be maintained by owner.

*Section 6.* This section establishes the conditions pertaining to the admission of any wastes having (a) a 5-day BOD greater than 300 ppm, (b) more than 350 ppm suspended solids, (c) any of the quantitative characteristics described in Section 3, and (d) an average daily flow greater than 2% of the average daily flow of the city.

*Section 7.* Where preliminary treatment facilities are provided for any wastes, they shall be maintained by the owner at his or her own expense.

*Section 8.* When required, the owner of any property served by a sewer carrying industrial wastes shall install a suitable manhole for observation, sampling, and measuring.

*Section 9.* All measurements and analyses of the characteristics of waters and wastes referred to in Section 3 or 6 shall be determined in accordance with standard methods (American Public Health Association 1955).

*Section 10.* No statement contained in this article shall preclude any special agreement or arrangement between the city and any industry.

Municipal ordinances change with time as a result of changing federal and state regulations and the cost of service. Table 10.2 contains the 1994 sewer-use ordinance from the city of Palo Alto, California. The reader is advised to compare the ordinance provisions shown in Table 10.1 with those published by Palo Alto. Selected discharge requirements from Palo Alto are found in Table 10.3.

### Sewer-Rental Charges

Sewer-rental charges are necessary to help meet the city's budget and to ensure that industry pays a fair share of the cost of disposing its wastes. Several methods can be used to charge for sewer service: (1) an *ad valorem* tax on property, which is the traditional method in more than 80% of U.S. communities and is successful in small towns and villages; (2) special assessments, with charges set according to front footage; (3) sewer-rental charges (approximately one-sixth of municipalities with treatment plants use this method); (4) special contracts negotiated with industry; and (5) combination of two or more of the previous methods. In many cases, a municipality charges the industry or industries solely on the basis of water consumption. Although this may not always prove equitable, it has several advantages to the municipality and to the industries. First, the billing system is simplified, omitting the need for detailed and time-consuming cost procedures. Second, the system eliminates the need for measuring flows from the industries and their strength characteristics. Thus, the municipality treats industries just as it does householders, rather than as "culprits."

TABLE 10.2  
Sewer Use Ordinance, City of Palo Alto Regional Water Quality Control Plant (September 1995)

The City of Palo Alto Sewer Use Ordinance reflects the current thinking and concerns expressed by the Environmental Protection Agency as well as the State of California, and therefore contains many pages and great detail. Elements include:

- Industrial waste discharge permit and procedure
- Compliance schedules
- New and existing sources (of discharges)
- Reporting requirements
- Personnel orientation
- Modification, suspension, or revocation of industrial wastes discharge permit
- Permit issuance, denial, modification, revocation, or suspension hearing
- Discharger monitoring
- Trucker's discharge permit
- Limitations on point of discharge
- Confidentiality
- Accidental discharge prevention
- Storage of hazardous materials
- Discharger self-monitoring
- Prohibitions
- Copper-based root control chemicals
- Grease disposal and pretreatment
- Strom drains: threatened discharges
- Standards

<i>Toxicant</i>	<i>Instantaneous Maximum Concentration Allowable</i>
Arsenic	0.1 mg/L
Barium	5.0
Beryllium	0.75
Boron	1.0
Cadmium	0.1
Chromium, hexavalent	1.0
Chromium, total	2.0
Cobalt	1.0
Copper	2.0
Cyanide	1.0
Formaldehyde	5.0
Lead	0.5
Manganese	1.0
Mercury	0.05
Nickel	0.5
Phenols	1.0
Selenium	1.0
Silver	0.25
Zinc	2.0

TABLE 10.3  
Maximum Allowable Discharge Limits for Wastewater

<i>Pollutant</i>	<i>Maximum Concentration Allowable (mg/L)</i>
Arsenic	0.1
Barium	5.0
Beryllium	0.75
Boron	1.0
Cadmium	0.1
Chromium (Hex)	1.0
Chromium (Total)	2.0
Cobalt	1.0
Copper <sup>a</sup>	2.0
Cyanide	1.0
Fluoride <sup>b</sup>	65
Formaldehyde	5.0
Lead	0.5
Manganese	1.0
Mercury	0.05
Nickel <sup>b</sup>	0.5
Phenols	1.0
Selenium	1.0
Silver <sup>b</sup>	0.25
Single toxic organic <sup>b</sup>	0.75
Total toxic organics <sup>b</sup>	1.0
Zinc	2.0
Oil/grease <sup>b</sup>	200
pH <sup>b</sup>	5.5–11.0
Suspended solids <sup>b</sup>	3,000
Total dissolved solids <sup>b</sup>	5,000

<sup>a</sup>For discharge >50,000 gpd, the maximum concentration will be one-half of value listed.

<sup>b</sup>Copper limit –0.25 mg/L, effective 7/1/98.

In considering charges, fixed costs such as operation, maintenance, and debt retirement should all be taken into account. A portion of each of these three costs can be charged to all users of the sewer system, and the remaining portion to property owners having access to the system. This is done by itemizing the cost of each component unit of the sewer system and then allocating percentages of the annual cost of each unit to users and the rest to property owners. Total annual charges to users and property owners are determined from the summation of unit costs. The total share allocated to property owners may now be prorated according to individual property valuations (or sometimes front footages). The user's share necessitates additional prorating based on the

following waste factors: volume, suspended solids, BOD, and (sometimes) chlorine demand. This is carried out in the computations of the user's share for each unit. If the unit is designed solely on a volume basis, such as the main sewage pumps, the entire user's share is charged to volume contributors of suspended solids and 10% to contributors of BOD. If the volume of sewage is based on water consumption and the supply is private (wells or river water), a meter is normally supplied by the industry for flow measurement.

When all user charges attributed to volume, solids, and BOD are added, one obtains the total user cost for each category. The total of the three in turn represents the user's share of the annual sewer costs, and the total of the user's and property owners' shares represents the complete annual sewer costs.

Schroepfer (1951) uses the following example to illustrate a fair allocation of costs. The total annual cost of operating a sewage-disposal system in a certain town consists of the following:

1. Fixed charges:	
Intercepting sewers <sup>1</sup>	\$35,000
Treatment plant <sup>1</sup>	\$75,000
2. Operating and maintenance costs:	\$70,500
Total	\$180,500

Table 10.4 shows the allocation of the fixed charges for the sewers and treatment plant, Table 10.5 the allocation of the operation and maintenance costs, and Table 10.6 the allocation of fixed and operation charges. Figures 10.2 and 10.3 illustrate the prorating of the fixed charges of the sewers and treatment plant.

Property owners' charges should be distributed according to assessed evaluation, which in the example under discussion is taken to be \$20,000,000. Therefore, \$2.88 per \$1,000 of property valuation will be charged to property owners. User charges depend on flow, solids, and BOD, as stated previously. Hence, the annual flow and the quantities of each type of these waste loads must either be determined after the first year's operation or be estimated prior to establishing the users' charges for the year. The third column of Table 10.7 lists the unit rates obtained from the data given in columns 1 and 2.

As the twentieth century came to an end, municipal services and treatment facilities became more complete and sophisticated. As a result, joint treatment with industrial wastes also became more complicated, demanding of industry, and protective of municipalities. It still occurred, but with many more safeguards to protect the overall joint system. Also, both parties became more acutely aware of the net result of the joint system on the receiving environment and the sewage system.

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<sup>1</sup>Capital investment for intercepting sewers, \$700,000, and for treatment plant, \$1,500,000. Debt retirement is 5% per year (total interest and principal).

TABLE 10.4  
Allocation of Fixed Costs

Units	<i>Chargeable to Property Owners</i>				<i>Users' Share Chargeable to</i>					
					<i>Volume</i>		<i>Suspended Solids</i>		<i>BOD</i>	
	<i>Total Fixed Costs, \$</i>	<i>%</i>	<i>\$</i>	<i>Chargeable to Users, \$</i>	<i>%</i>	<i>\$</i>	<i>%</i>	<i>\$</i>	<i>%</i>	<i>\$</i>
Intercepting sewers	35,000	64	22,300	12,700	100	12,700				
<i>Treatment plant</i>										
Main pumping station										
Equipment	1,500	40.5	600	900	100	900				
Structures	1,250	64	800	450	100	450				
Screen and grit chambers	1,500	64	950	550	60	330	40	220		
Preliminary sedimentation tanks	4,500	40.5	1,800	2,700	85	2,300	15	400		
Trickling filters	30,000	25	7,500	22,500	10	2,250			90	20,250
Final sedimentation tanks	9,000	30	2,700	6,300	50	3,150			50	3,150
Receiving pumps	750	25	200	550					100	550
Chlorination tanks and equipment	2,000	35	700	1,300	40	520			60	780
Digester tanks and receiving filters	8,000	30	2,400	5,600			100	5,600		
Subtotal	58,500	30.3	17,650	40,850	24.2	9,900	15.2	6,220	60.6	24,730
Main control building	7,500	30.3	2,300	5,200	24.2	1,310	15.2	790	60.6	3,100
Plant water supply	2,500	30.3	800	1,700	24.2	410	15.2	260	60.6	1,030
Roads and grounds	2,500	30.3	800	1,700	24.2	410	15.2	260	60.6	1,030
Plumbing and heating	4,000	30.3	1,200	2,800	24.2	680	15.2	430	60.6	1,690
Total plant costs	75,000	30.3	22,750	52,250	24.2	12,710	15.2	7,960	60.6	31,580
Total fixed costs	110,000	41	45,050	64,950	39.2	25,410	12.2	7,960	48.6	31,580

Source: From Nemerow (1987).

TABLE 10.5  
Allocation of Operation and Maintenance Costs

<i>Unit</i>	<i>Total</i>	<i>Chargeable to Property Owners</i>		<i>Chargeable to Users, \$</i>		<i>Volume</i>	<i>Users' Share Chargeable to Suspended Solids</i>			
		<i>%</i>	<i>\$</i>	<i>\$</i>	<i>%</i>		<i>%</i>	<i>BOD</i>		
								<i>\$</i>	<i>%</i>	<i>\$</i>
Intercepting sewers	2,200	60	1,300	900	60	500	40	400		
Main pumping station	9,200	17	1,600	7,600	100	7,600				
Preliminary treatment	6,700	50	3,400	3,300	50	1,700	50	1,600		
Secondary treatment	13,500	15	2,000	11,500	10	1,200			90	10,300
Effluent chlorination	5,200	15	800	4,400	10	400			90	4,000
Sludge disposal	17,500	5	900	16,600			100	16,600		
General	5,000	15	800	4,200	25	1,000	43	1,800	32	1,400
Supervisory	6,200	15	900	5,300	25	1,300	43	2,300	32	1,700
Collection and billing	5,000	15	800	4,200	25	1,000	43	1,800	32	1,400
<b>Total</b>	<b>70,500</b>	<b>17.8</b>	<b>12,500</b>	<b>58,000</b>	<b>25.4</b>	<b>14,700</b>	<b>42.1</b>	<b>24,500</b>	<b>32.5</b>	<b>18,800</b>

Source: Nemerow (1987).

TABLE 10.6  
Summary of Allocation of Fixed and Operating Cost

	<i>Chargeable to</i>			
	<i>Users</i>		<i>Property Owners</i>	
<i>Fixed Costs</i>	%	\$	%	\$
Sewers	36	12,700	64.0	22,300
Treatment plant	69.7	52,250	30.3	22,750
Operation and maintenance costs	82.2	58,000	17.8	12,500
Totals		122,950		57,550
Averages	68.1		31.9	

Source: Nemerow (1987).

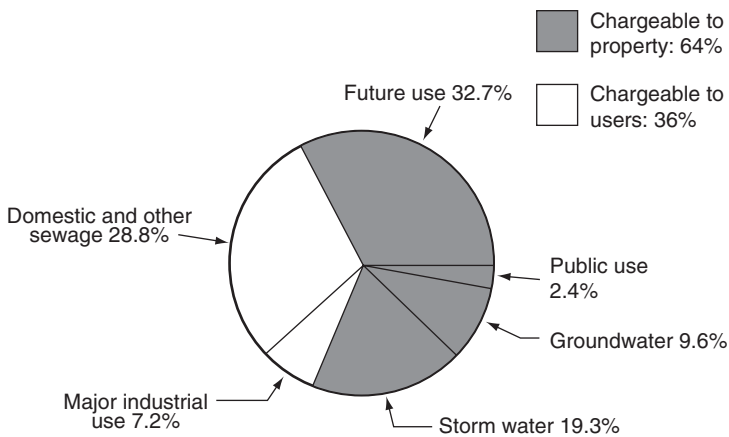


FIGURE 10.2. Allocation of fixed charges on the intercepting sewers. (Adapted from Schroepfer 1951)

### Case History of Project for Joint Disposal of Untreated Industrial Wastes and Domestic Sewage

For the purposes of this discussion, I consider the case of two relatively small municipalities containing 27 small industries (mostly tanneries) that require adequate and effective treatment of their wastes. The problem presents a challenge in engineering, economics, and administration.

#### Existing Situation

Cayadutta Creek rises in the central part of Fulton County in New York State, flows generally south for about 14 miles through the cities of Gloversville and Johnstown, and

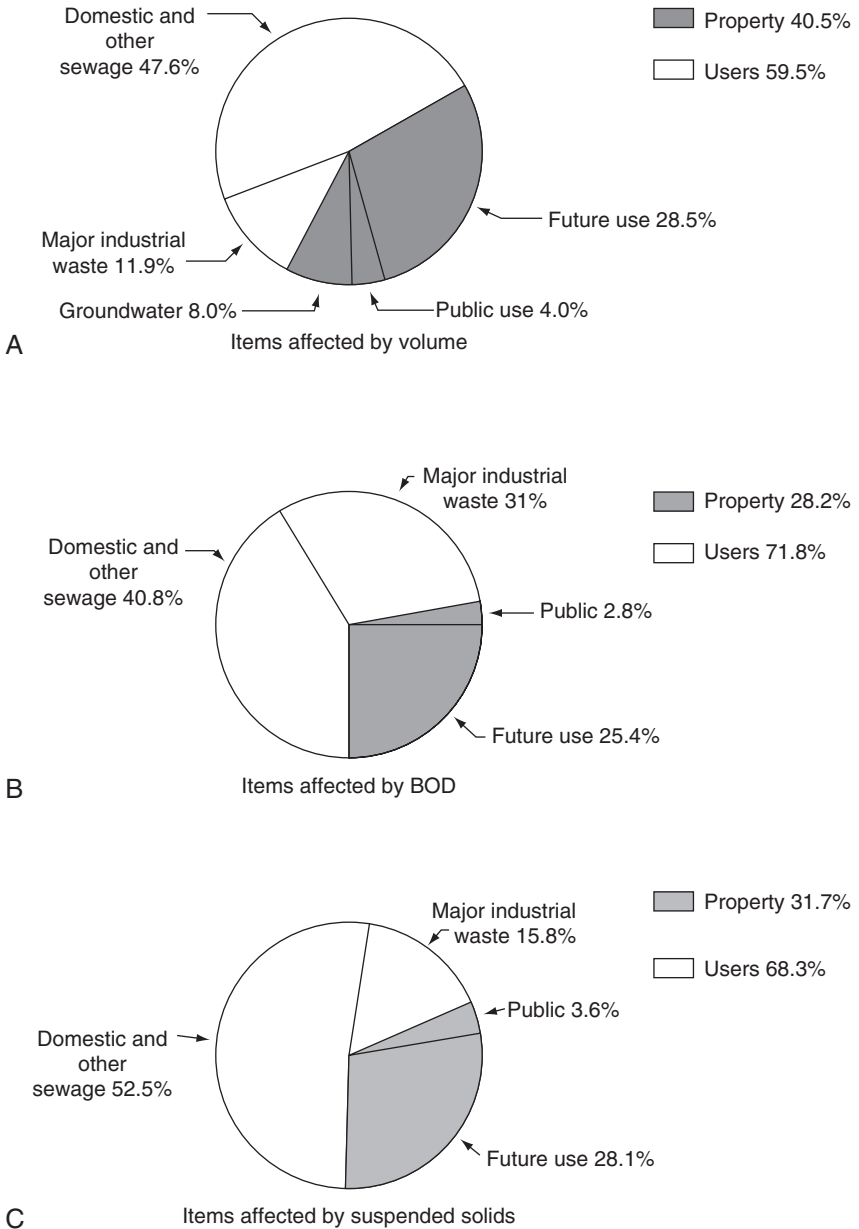


FIGURE 10.3. Allocation of fixed costs for treatment plant. (A) Items affected by volume. (B) Items affected by BOD. (C) Items affected by suspended solids. (Adapted from Schroepfer 1951.)

TABLE 10.7  
Calculation of Users' Charges Based on Three Factors

	<i>Annual Quantity</i>	<i>Total, \$</i>	<i>Unit Rate, \$</i>
Volume of flow	1,370 million gal	40,000	2.93/1000 gal
Suspended solids	3,647,000 lb	32,460	0.89/100 lb
BOD	3,847,000 lb	50,380	1.40/100 lb

*Source:* Adapted from Schroeffer (1951).

enters the Mohawk River at Fonda (Figure 10.4). The total catchment area covers 62 square miles above Station 6. There are no official gauging stations on this stream, but approximate flow data for a comparatively short time (1898–1900) are available. This creek has been characterized by an expert state hydrologist, a member of the U.S. Geological Survey, as similar to that of Kayaderosseras Creek, which is located in Saratoga County and drains into the Hudson River basin.

Ninety-one percent of the population of the Cayadutta Creek catchment area is concentrated in the cities of Johnstown and Gloversville and the village of Fonda. In 1952, New York State cited this creek as “one of the most grossly polluted streams in the state.” From within the city of Gloversville to the junction with the Mohawk River, the stream was entirely unsuited for the support of fish life, whereas formerly it was trout water throughout its entire length. It has been stated (M. Vrooman, *March 10, 1950, Report to City of Gloversville*) that the dry weather flow of Cayadutta Creek is higher than the average for streams in the state, because of the nature of the watershed, the sandy soil, and the larger wooded area. Vrooman also stated that “the average daily flow of the creek at the Gloversville sewage-treatment plant is 17 million gallons and the low measured dry weather flow is 4.2 million gallons.” These figures were evidently obtained from separate, independent, and unofficial flow measurements. The tanning industry is an old one in the United States and has a record of contributing to the damaging pollution of Cayadutta Creek. The National Tanners Association (private communication) estimates that the Fulton County area has been losing about one plant every 4 years. However, there has been more glove- and garment-leather demand as the population of the United States rises. They predict, therefore, that the overall demand for glove and garment leather (produced in Fulton County) will continue slowly upward, but it will be met by fewer plants with increased production.

The sewage and wastes from the cities of Gloversville and Johnstown are discharged into Cayadutta Creek. In 1960, Gloversville had a population of 21,741 while that of Johnstown was 10,390 (Figures 10.4 and 10.5). Almost the entire urban population is served by public sewer systems, but only half of the system is tributary to a sewage-treatment plant, which serves the people and industry of Gloversville. It consists of a bar screen, grit chamber, two antiquated Dortmund-type primary settling basins, a fixed-nozzle trickling filter, one final Dortmund-type settling basin, and some sludge-drying beds. The plant was built in the early 1900s and is incapable of handling more than half the wastewater at the present flow rates.

The tanning industry retained a New York City consulting firm to represent its interests in this problem. The two cities retained a local consulting engineering firm,

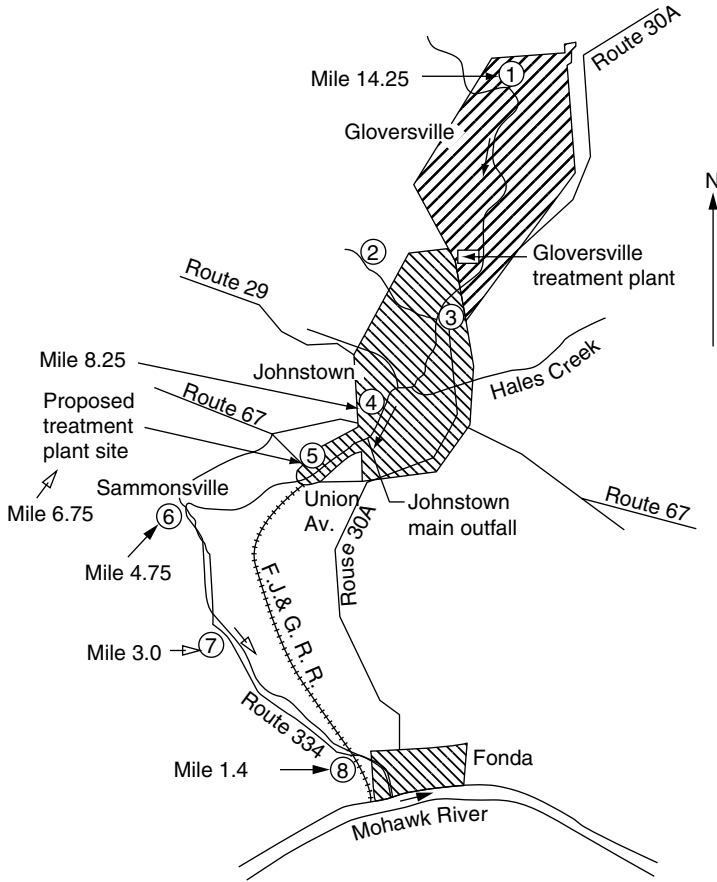


FIGURE 10.4. Cayadutta Creek.

which in turn retained the author to advise them on study procedures and solutions to the pollution problem in Cayadutta Creek.

### Stream Survey

A stream survey is an essential part of any well-conceived waste-treatment study. Ideally, a survey designed to study the oxygen-sag curve should be carried out during extremely hot weather, extremely low stream flow, and typical high organic matter loading. It is seldom possible to conduct a stream survey under all of these “ideal” conditions. In this study, I was particularly fortunate to collect stream samples during extremely low-flow conditions—comparable to those that may be expected to occur for a 7-day period only once in 10 years—while the municipal and industrial pollution loads were considered to be above average. Although stream temperatures were not high (11–14°C), these values are never very high because of the relatively cold mountain water diluting

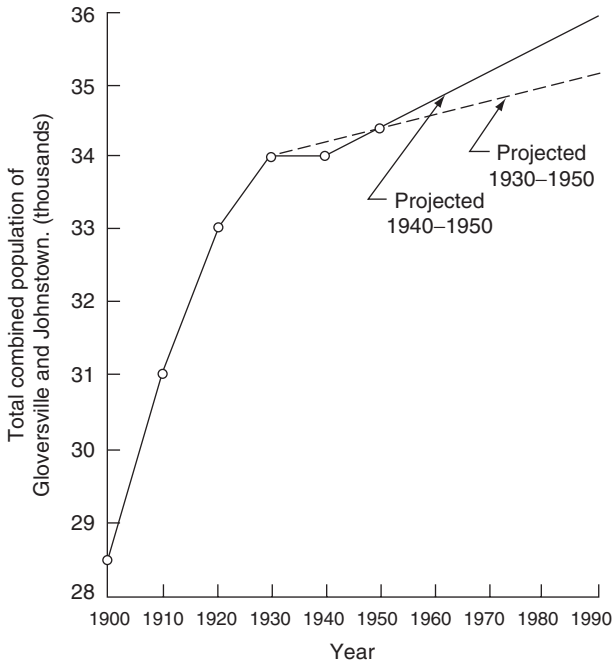


FIGURE 10.5. Population of Gloversville and Johnstown, 1900–1990.

the wastes. For example, during the state survey in 1951, samples collected on August 22 and 23 at Stations 5 and 6 showed temperatures of only 15–19°C.

During October 1964, the creek was visited and examined at various locations and dissolved-oxygen values were determined in order to locate the sag curve points. After an initial appraisal and a trial survey, the creek was sampled at the eight stations shown in Figure 10.4. After the first day samples were collected only from Stations 1, 5, and 6 on six days at different times during each day. Composite samples were analyzed for dissolved oxygen, BOD, and temperature. In addition, the creek flow was measured on each sampling date at Station 6. These results are shown in Table 10.8. Flow times are shown in Table 10.9, a summary of the BOD and flow data in Table 10.10, the BOD curves for Stations 5 and 6 in Figure 10.6, flow data from a similar gauged creek in Table 10.11, the probability of the minimum flow data occurring in Table 10.12 and Figure 10.7, and a multiple-regression technique analysis of the stream data in Tables 10.13 and 10.14.

#### *Cayadutta Creek Analysis*

Using the multiple-regression method, the following three equations lead to dissolved oxygen solutions. When solved simultaneously, the three equations will yield the “best” equation that relates the dissolved-oxygen sag to the BOD, flow, and temperature at the bottom of the sag (Station 6).

TABLE 10.8  
Cayadutta Creek Analyses in October 1964

Station and Milage	Date	Time	DO, ppm	Flow, cfs	<i>BOD, ppm</i>					Water Temp., °C
					Day 1	Day 2	Day 3	Day 4	Day 5	
1. Bleeker St. Bridge, Gloversville (clean H <sub>2</sub> O site) (14.25)	10/8		10.12						8.0	8
	10/12		9						8.5	13
	10/13		10.0						9.5	12
	10/14		10.5						10.0	10
	10/15		9						8.5	11
	10/17		9.5						9.3	12
	10/18		10.0						8.9	11
4. Main St., Johnstown (8.25)	10/8		1.0						310	12.5
	10/12	1:30	1.9						240	15
	10/13	10:15	0.5						290	13
	10/14	9:00	5.1						340	10
	10/15	4:00	2.7						280	12
	10/17	11:05	6.2						240	12
	10/18	1:30	6.0						30	12
5. Harding property below Johnstown (6.75)	10/8		2.75		140	230	260	290	340	11.5
	10/12	2:00	2.8		110	180	220	260	290	15
	10/13	10:25	5.0		100	130	130	140	150	14
	10/14	9:30	3.1		120	190	170	180	200	14
	10/15	4:30	3.0		100	140	160	210	220	13
	10/17	11:25	5.4		100	70	130	150	160	14
	10/18	2:05	5.5		70	70	100	140	140	15

TABLE 10.8 (continued)

Station and Milage	Date	Time	DO, ppm	Flow, cfs	<i>BOD, ppm</i>					Water Temp., °C
					Day 1	Day 2	Day 3	Day 4	Day 5	
6. Sammons- ville Bridge (4.75)	10/8		2.2	59.4	130	200	270	300	330	13
	10/12	2:25	1.8	51	140	170	250	230	240	14
	10/13	10:45	1.1	44	40	70	60	80	140	12
	10/14	9:45	4.6	39	110	150	140	150	180	11
	10/15	4:50		39	40	110	150	160	160	12
	10/17	11:55	4.8	12.2	40	30	100	100	70	12
	10/18	2:40	4.8	12.2	40	30	50	50	40	13
	10/31			34						
	11/1			42						
7. Rt. 334, adjacent to Peresse Rd., Berryville Cross (3.0)	10/8		1.25					190	11	
	10/12	2:45	0					200	14	
	10/13	11:10	4.1					140	12	
	10/14	10:05	5.0					170	11	
	10/15	5:15	3.9					80	10	
	10/17	12:15	1.8					70	11	
	10/18	3:10	4.0					50	11	
8. Rt. 334, 1 mile north of Fonda next to Cannarella house (1.4)	10/8		5.1					180	10.5	
	10/12	3:05	3.5					90	13	
	10/13	11:30	5.1					140	11	
	10/14	10:20	5.1					160	11	
	10/15	4:30	5.0					80	12	
	10/17	12:45	3.6					100	11	
	10/18	3:30	4.5					40		

TABLE 10.9  
Time of Flows from Station 5 Downstream Obtained 1 Week Before Stream-Sampling Program in October 1964

Site	Distance Between Points, miles	Time	Fall, ft
Start at Harding farm (Station 5)			
To old power dam	1	45 min	70
To bridge at Sammonsville (Station 6)	1	2 hr	20
To bridge at Fonda Ave.	1.75	2 hr	80
To railroad bridge	1.50	2 hr 40 min	55
Begin slack water of Mohawk River	1	2 hr 30 min	50
Total	6.25	9 hr 55 min	275

TABLE 10.10  
Summary of 7-Day Sampling of Cayadutta Creek in Dry Period, from 10/8/64 to 10/18/64

Station	Reading	Average of Seven Samples	Range
1	DO, ppm	9.73	9–10.5
	Temp., °C	11	8–13
	5-day BOD, at 20°C, ppm	8.96	8–10
5	DO, ppm	3.93	2.75–5.5
	Temp., °C	13.8	11.5–15
	5-day BOD, at 20°C, ppm	214	140–340
	L	270	
		(projected factor 1.26)	
	1-day	106	70–140
	2-day	144	70–230
6	3-day	167	100–260
	4-day	196	140–290
	DO, ppm	3.17	1.1–4.8
	Temp., °C	12.4	11–14
	5-day BOD, at 20°C, ppm	166	40–330
	L	230	
		(projected factor 1.39)	
	1-day	77	40–140
	2-day	109	30–200
3-day	146	50–270	
4-day	153	50–300	
Flow, <sup>a</sup> cfs <sup>b</sup>	36.7	12.2–59.4	

<sup>a</sup>Time of travel between Stations 5 and 6 was 2 hr 45 min (0.115 days).

<sup>b</sup>Flow for 10/12/64 computed as arithmetic average of flow on 10/8/64. This flow represents approximate value of 7-day consecutive low flow likely to occur in Cayadutta Creek below Johnstown once in 10 years:  $\% \times 20 = 13.8$  cfs for entire Cayadutta Creek (slightly less below Johnstown). The 20 cgs in the equation is the minimum 7-day flow for Kayaderosseras Creek (*New York State Upper Hudson River Drainage Basin Survey Series Report no. 2*, p. 244).

Source: Nemerow (1987).

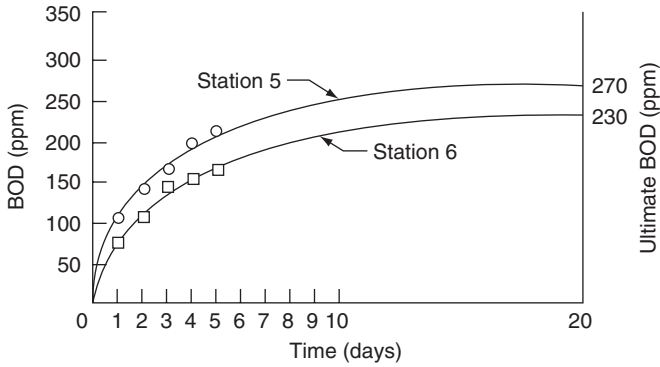


FIGURE 10.6. Laboratory BODs for Stations 5 and 6 at 20°C. Each point represents an average of seven samples collected from the creek on 7 different days at different times of day, all during a drought flow period (October 8–18, 1964).

$$b_1 \sum X_1^2 + b_2 \sum X_1 X_2 + b_3 \sum X_1 X_3 = \sum X_1 Y, \tag{1}$$

$$b_1 \sum X_1 X_2 + b_2 \sum X_2^2 + b_3 \sum X_2 X_3 = \sum X_2 Y, \tag{2}$$

$$b_1 \sum X_1 X_3 + b_2 \sum X_2 X_3 + b_3 \sum X_3^2 = \sum X_3 Y. \tag{3}$$

From Table 10.15, we can substitute numerical data in order to find  $b_1$ ,  $b_2$ , and  $b_3$ . From Equation (1), we obtain

$$364.78b_1 + 4.58b_2 + 125.62b_3 = -43.78. \tag{4}$$

Dividing Equation (4) by 364.78 yields

$$b_1 + 0.01256b_2 + 0.3435b_3 = -0.1200. \tag{5}$$

Multiplying Equation (4) by 0.01255 gives

$$4.58b_1 + 0.05748b_2 + 1.5728b_3 = -0.5494. \tag{6}$$

We next apply Equation (2) and obtain

$$4.58b_1 + 10.68b_2 + 0.14b_3 = 3.02. \tag{7}$$

Subtracting Equation (6) from (7) yields

$$10.62252b_2 - 1.4328b_3 = 3.5694. \tag{8}$$

TABLE 10.11

Minimum Flow Data of Measured Creek Compared with Cayadutta Creek

<i>Year</i>	<i>Minimum Day Flow of Kayaderosseras Creek,<sup>a</sup>cfs</i>	<i>Equivalent Minimum Daily Flow<sup>b</sup> of Cayadutta Creek (Station 6), cfs</i>
1927	13	8.9
1928	18	12.4
1929	24	16.5
1930	19	13.1
1931	19	13.1
1932	20	13.8
1933	19	13.1
1934	20	13.8
1935	34	23.4
1936	20	13.8
1937	21	14.5
1938	20	13.8
1939	20	13.8
1940	23	15.9
1941	15	10.3
1942	23	15.9
1943	29	19.3
1944	21	14.5
1945	26	17.9
1946	20	13.8
1947	22	15.2
1948	18	12.4
1949	14	9.6
1950	23	15.9
1951	32	22
1952	31	21.4
1953	20	13.8
1954	23	15.9
1955	20	13.8
1956	32	22
1957	19	13.1
1958	20	13.8
1959	18	12.4
1960	25	17.2

<sup>a</sup>Hydrologically similar to Cayadutta Creek.<sup>b</sup>Calculated by dividing the drainage area of Cayadutta Creek (62 sq.mi.) by that of Kayaderosseras Creek (90 sq.mi.) and multiplying by the known rate of flow for the latter, that is,  $\frac{62 \times 13}{90} = 8.9$ .

Source: Nemerow (1987).

TABLE 10.12  
 Normal Probability Distribution Analysis of Data (1927–1960)  
 from Table 16.9

<i>Flow, cfs</i>	<i>Magnitude (M)</i>	<i>Plotting Position<sup>a</sup></i>
8.9	1	0.0286
9.6	2	0.0572
10.3	3	0.0858
12.4	4	0.1143
12.4	5	0.1430
12.4	6	0.1715
13.1	7	0.2000
13.1	8	0.2290
13.1	9	0.2570
13.1	10	0.2860
13.8	11	0.3140
13.8	12	0.333
13.8	13	0.371
13.8	14	0.400
13.8	15	0.428
13.8	16	0.458
13.8	17	0.486
13.8	18	0.515
13.8	19	0.544
14.5	20	0.571
14.5	21	0.600
15.2	22	0.629
15.9	23	0.658
15.9	24	0.685
15.9	25	0.715
15.9	26	0.744
16.5	27	0.770
17.2	28	0.800
17.9	29	0.829
19.3	30	0.858
21.4	31	0.887
22.0	32	0.916
22.0	33	0.945
23.4	34	0.974

<sup>a</sup>Calculated from the formula  $M/(N + 1)$ , where  $M$  = magnitude in decreasing order of drought severity and  $N$  = number of values.

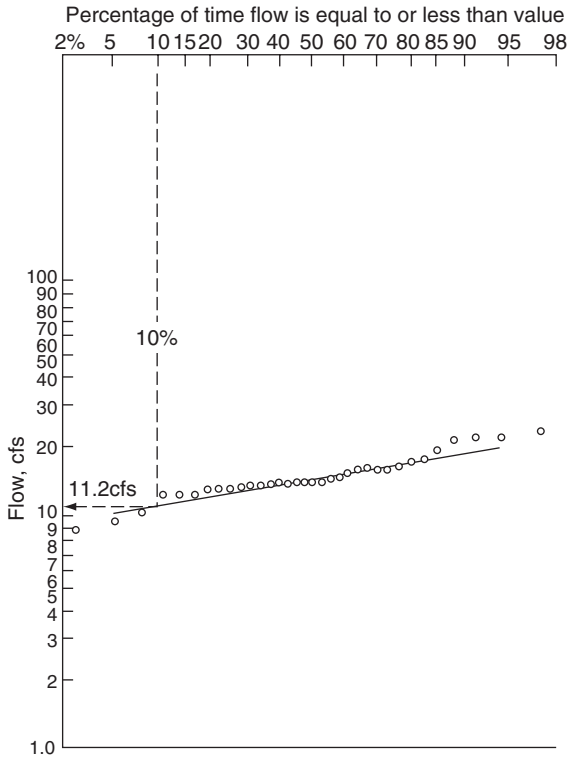


FIGURE 10.7. Minimum flow of Cayadutta Creek and expected recurrence of this level.

TABLE 10.13

Summary of Data Required from Cayadutta Creek Analyses in October 1964 for Churchill Method of Analysis

Date	DO, ppm		Drop in DO, ppm (Y)	BOD at Sag, ppm	Temp. at Sag, °C	Flow at Sag, cfs
	Station 1	Station 6				
10/8	10.1	2.2	7.9	330	13	59.4
10/12	9.0	1.8	7.2	240	14	51
10/13	10.0	1.1	8.9	140	12	44
10/14	10.5	4.6	5.9	180	11	39
10/15	9.0	2.9	6.1	160	12	39
10/17	9.5	4.8	4.7	70	12	12.2
10/18	10.0	4.8	5.2	40	13	12.2

DO, dissolved oxygen.

TABLE 10.14  
Churchill Analysis Applied to Cayadutta Creek Data

<i>Date</i>	<i>Dissolved Oxygen</i>		<i>Drop in DO, ppm (Y)</i>	<i>BOD at Sag, 1000/ppm (X<sub>1</sub>)</i>	<i>Temp. at Sag, °C (X<sub>2</sub>)</i>	<i>Flow at Sag, 100/cfs (X<sub>3</sub>)</i>	<i>Y<sup>2</sup></i>
	<i>At Station 1, ppm</i>	<i>At Station 6, ppm</i>					
10/8/64	10.1	2.2	7.9	3.03	13	1.68	62.41
10/12/64	9.0	1.8	7.2	4.17	14	1.96	51.84
10/13/64	10.0	1.1	8.9	7.14	12	2.27	79.21
10/14/64	10.5	4.6	5.9	5.56	11	2.56	34.81
10/15/64	9.0	2.9	6.1	6.25	12	2.56	37.21
10/17/64	9.5	4.8	4.7	14.29	12	8.20	22.09
10/18/64	10.0	4.8	5.2	25.00	13	8.20	27.04
Totals			45.9	65.44	87	27.43	314.61
Means			$\bar{Y}$	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$	
			6.56	9.35	12.4	3.92	$n\bar{Y}^2$
Corrected items <sup>a</sup>							301.21
Corrected totals							13.40

<sup>a</sup>*n* = number of samples (7).

TABLE 10.15  
Summary of 24-Hour Sampling Results

<i>Date</i>	$YX_1$	$YX_2$	$YX_3$	$X_1'$	$X_1X_2$	$X_1X_3$	$X_2^2$	$X_2X_3$	$X_3^2$
10/8/64	23.94	102.7	13.27	9.18	39.39	5.09	169	21.84	2.82
10/12/64	30.02	100.8	14.12	17.39	58.38	8.17	196	27.44	3.84
10/13/64	63.55	106.8	20.20	50.98	85.68	16.21	144	27.24	5.15
10/14/64	32.80	64.9	15.10	30.91	61.16	14.23	121	28.16	6.55
10/15/64	38.13	73.2	15.62	39.06	75.00	16.00	144	30.72	6.55
10/17/64	67.16	56.4	38.54	204.20	171.48	117.48	144	98.40	67.24
10/18/64	130.00	67.6	42.64	625.00	325.00	205.00	169	106.60	67.24
Totals	385.60	572.4	159.49	976.72	816.00	381.18	1087	340.40	159.39
Means	$nYX_1$	$nYX_2$	$nYX_3$	$n\bar{X}_1^2$	$n X_1\bar{X}_2$	$n X_1\bar{X}_3$	$n\bar{X}_2^2$	$nX_2X_3$	$n\bar{X}_3^2$
Corrected items <sup>a</sup>	429.38	569.38	180.04	611.94	811.51	256.56	1076.32	340.26	107.56
Corrected totals	-43.78	3.02	-20.55	364.78	4.58	125.62	10.68	0.14	51.83

Dividing Equation (8) by 10.62252, we obtain

$$b_2 - 0.1349b_3 = 0.3360. \tag{9}$$

Multiplying Equation (4) by  $-0.3435$ , we get

$$-125.32b_1 - 1.573b_2 - 43.047b_2 = +15.038 \tag{10}$$

Next, we multiply Equation (8) by  $+0.1443$ :

$$1.533b_2 - 0.20675b_3 = 0.51506 \tag{11}$$

Finally, we apply Equation (3) and obtain

$$125.32 b_1 + 0.04b_2 + 51.83b_3 = -20.55. \tag{12}$$

Adding Equations (10), (11), and (12), we have

$$8.5763b_1 = -4.99694, \tag{13}$$

$$b_3 = -0.5826. \tag{14}$$

From Equation (9),

$$b_2 - (-0.07859) = 0.3360,$$

$$b_2 = +0.2574. \tag{15}$$

From Equation (5),

$$b_1 + (0.00323) + (-0.20012) = -(0.1200),$$

$$b_1 + 0.00323 - 0.0012 = -0.1200,$$

$$b_1 = 0.0769. \tag{16}$$

As a check, we substitute the following in Equation (12):

$$125.32 (0.0769) + 0.04 (0.2574) + 51.83 (-0.5826)$$

$$= -20.55$$

$$9.6471 + 0.010296 - 30.1962 = -20.55$$

$$-20.5488 = -20.55$$

$$Y = a + b_1\bar{x}_1 + b_2\bar{x}_2 + b_3\bar{x}_3$$

$$a = \bar{Y} - (b_1\bar{X}_1 + b_2\bar{X}_2 + b_3\bar{X}_3)$$

$$a = 6.56 - [(0.07769 \times 9.35) + (0.2574 \times 12.4) + (-0.5826 \times 3.92)]$$

$$a = 6.56 - [0.7190 + 3.1918 - 2.2838]$$

$$a = 6.56 - 1.6270$$

$$a = 4.9330.$$

Therefore, the Cayadutta Creek equation is

$$y = a + bx_1 + b_2x_2 + b_3x_3$$

$$Y = 4.9330 + 0.0769X_1 + 0.2574X_2 - 0.5826X_3,$$

where

$X_1$  = 5-day BOD (1,000/ppm) 20°C at Station 6

$X_2$  = temperature (°C)

$X_3$  = flow (100/cfs)

$Y$  = DO drop from Station 1 to Station 6 (ppm).

To verify this stream equation, we can substitute the actual observed stream values for  $X_1$ ,  $X_2$ , and  $X_3$  and obtain a calculated  $Y$  value, which can then be compared with the observed value for accuracy:

Date (1964)	Observed $Y$ (ppm)	Calculated $Y$ (ppm)
10/8	7.9	7.53
10/12	7.2	7.72
10/13	8.9	7.25
10/14	5.9	6.70
10/15	6.1	7.01
10/17	4.7	3.37
10/18	5.2	5.42

During the October 1964 study, the lowest flow was 12.2 cfs, the highest temperature 14°C, and the DO sag allowed was between 9.0 and 2.0 (i.e., 7.0) ppm.

To find the BOD load at sag, we calculate as follows:

$$Y = 4.9330 + 0.0769X_1 + 0.2574X_2 - 0.5826X_3$$

$$7.0 = 4.9330 + 0.0769X_1 + 0.2574$$

$$-0.5836 (100/12.2)$$

$$7.0 = 4.9330 + 0.0769X_1 + 3.6036 - 4.7773$$

$$3.2407 = 0.0769X_1$$

$$X_1 = 42.1417 = 1,000/\text{ppm}.$$

$$\text{ppm allowed} = 1,000/42.1417 = 23.73 \text{ ppm.} \quad (14)$$

The average BOD at sag was 166 ppm during the entire 7-day survey. Therefore, the BOD reduction required in the stream at Station 6 was

$$[(166-23.73)/166] \times 100 = 85.70\%.$$

Although the Streeter–Phelps method yielded values of  $k_1$  and  $k_2$ , which gave a Fair's  $f$  of about 35,<sup>2</sup> the results are not reliable because of the variability of wastes from one moment to the next as well as the multiple entrances of wastes into the stream. The only reliable procedure for evaluating the oxygen-sag characteristics is to collect many stream samples under these critical conditions and statistically correlate the data in order to obtain a stream equation. This method is commonly referred to as the *Churchill multiple-regression technique*. The stream equation represents the line that best fits the data for the conditions under which the samples were collected. Projection of the line beyond this range of conditions is not recommended, but extrapolations to different conditions within the range of existing data can be made with a reasonable degree of certainty. The stream equation for Cayadutta Creek, developed by extensive analysis, can be used to compute the BOD reductions necessary to maintain a certain minimum dissolved-oxygen level at a given temperature. These calculations are given below and in Figures 10.8 and 10.9.

To find the waste-treatment requirements, we use the stream equation developed during the low-flow critical period for Cayadutta Creek during the October 1964 study:

$$Y = 4.9330 + 0.0769 X_1 + 0.2574 X_2 - 0.5826 X_3,$$

$$X_1 = 1,000/\text{ppm BOD}$$

$$\text{when } X_2 = \text{temperature} = 12.4 \text{ (}^\circ\text{C)}$$

$$X_3 = 100/\text{cfs} = 100/12 \text{ (see Table 10.12)} = 8.33$$

$$Y = \text{DO sag from Station 1 to Station 6} = 9.73 - 2.00 = 7.73$$

$$7.73 = 4.9330 + 0.0769 X_1 + 0.2574 (12.4) \\ - 0.5826 (8.33)$$

$$7.73 + 4.85 - 4.9330 - 3.200 = 0.0769 X_1$$

$$12.58 - 8.133 = 4.447/0.0769 = X_1 = 57.75$$

$$\text{ppm} = 1,000/57.75 = 17.3 \text{ ppm at sag.}$$

<sup>2</sup>  $f = k_2/k_1 = \text{re-aeration rate/deoxygenation rate.}$

The BOD values for the 7 days of the survey at Station 5 were 340, 290, 150, 200, 220, 160, and 140 ppm, giving an average of 214 ppm. At Station 6, the values were 330, 240, 140, 180, 160, 70, and 40, with an average of 166 ppm. The percentage decrease in BOD between Stations 5 and 6 was

$$(214 - 116)/214 = 48/214 = 22.5\%.$$

The BOD (in pounds) being discharged at Station 5 on the 7 days of the survey was a total of 142,500 (see Table 10.11) and an average of 23,750 lb/day.

Taking  $23,750 \times 77.5\% = 18,400$  lb/day as the BOD left at Station 6, with no treatment at 12 cfs, 12.4°C, and an allowable DO deficit at the sag point of 8.65 ppm (10.65 - 2.0), we obtain an allowable 17.3 ppm BOD at the sag or

$$[(17.3 \times 12) / (1.54)] \times 8.34 = 1,122 \text{ lb/day.}$$

Since  $23,750 - 0.225 = 18,400$  lb/day, the BOD reduction required is

$$[(18,400 - 1,122) / (18,400)] \times 100 = (17,278) / (18,400) = 93.8\%.$$

At 12.4°C and the same DO sag (7.73 ppm), but at the increased stream flow of 20 cfs, we obtain an allowable BOD at the sag of

$$Y = 4.9330 + 0.0769 X_1 + 0.2574 X_2 - 0.5826 X_3$$

$$7.73 - 4.9330 - 3.2000 = 0.0769 X_1 - 0.5826 (100/20)$$

$$[(7.73 + 2.4130 - 8.1330)] / (0.0769) = X_1 = (2.0100)/(0.0769) = 26.05 \text{ ppm}$$

$$= 1,000/26.05 = 38.4 \text{ ppm}$$

$$\text{at } 38.4 \text{ ppm} \times 8.34 \times (20/1.54)$$

$$= 4,155 \text{ lb BOD at Station 6}$$

$$\text{BOD reduction required} = 14,245/18,400 \times 100 = 77.5\%.$$

At the same temperature (12.4°C) and the same DO sag (7.73 ppm), but at the average stream flow at the sag of 36.7 cfs (October 1964 survey), we obtain an allowable BOD at the sag of

$$Y = 4.9330 + 0.0769 X_1 + 0.2574 X_2 - 0.5826 X_3$$

$$7.73 = 4.9330 \times 0.0769 (X_1) + 0.2574 (12.4^\circ\text{C})$$

$$-0.582 (100/36.7)$$

$$7.730 + 1.590 - 4.9330 - 3.2000 = 0.0769 X_1$$

$$(9.3200 - 8.1330) / 0.0769 = 1.1890/0.0769 = 15.45 = X_1$$

$$\text{ppm} = 1,000/15.45 = 64.8$$

at  $64.8 \text{ ppm} \times 8.34 \times 36.7/1.54 = 12,850 \text{ lb BOD at Station 6}$

$$\begin{aligned} \text{BOD reduction required} &= [(18,400 - 12,850) / (18,400)] \times 100 \\ &= 5,550/18,400 = 30.2\%. \end{aligned}$$

Figures 10.8 and 10.9 indicate that to maintain 2 ppm of dissolved oxygen (a preselected safe value for this class of stream) of loadings of 23,750 lb BOD/day at the bottom of the sag at a temperature of 12.4°C, BOD reductions of 65–94% at 23,750 lb/day loading and 77–97% at 35,019 lb/day would be required for critical stream flows of 12–25 cfs.

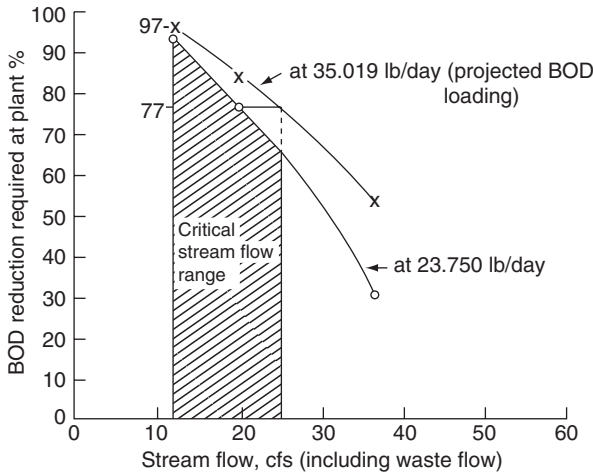


FIGURE 10.8. BOD reduction required at Station 5, at 12.4°C and 2 ppm DO remaining and based on a waste discharge of 23,750 lb/day.

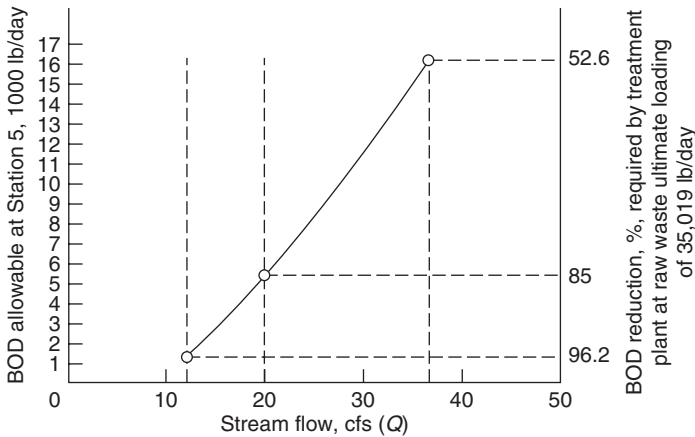


FIGURE 10.9. Special design curve for computing treatment plant requirements at 12.4°C and 2 ppm DO at Station 5.

### Composite Waste Sampling

Waste samples were collected hourly for a 24-hour period from three sources: the Johnstown 30-in. sewer (main), the Johnstown 8-in. sewer (Tynville), and the Gloversville sewage plant, on November 17 and December 3, 1964. Similar samples were collected for a 24-hour period on January 21, 1965, except that the 8-in. Johnstown sewer was eliminated as being relatively insignificant. Weirs were installed in the Johnstown lines to record the total flows from Johnstown and from Gloversville. Samples were collected and composited according to the rate of flow at the hour of sampling. A summary of the proportionate pollutional loads and volumes for these 3 days is shown in Table 10.16. Additional 24-hour composites from each line were collected according to flow and analyzed on February 18, March 30, April 21, and May 6, 1965 (Table 10.17).

### Composite Waste Analyses

The hourly data revealed several significant findings:

1. *Slugs*, which can be defined for this situation as instantaneous discharges of high volumes of waste, concentrated acid or alkali, or BOD, are apparently not a major problem. The flow increases by about 100% of the daily average, for

TABLE 10.16  
Summary of 24-Hour Sampling Results

Source	Date	Pounds/ Day	BOD Load			Flow		Suspended Solids		
			% in Peak Period <sup>a</sup>	% of Daily Total	mgd	Ratio of Peak Period to Daily Average	% of Daily Total	Pounds/ Day	% in Peak Period	% of Daily Total
Gloversville	11/17/64	13,350	45.2	67.5	3.80	1.38	66	27,550	80.8	87.5
	12/3/64	13,350	50.2	56.3	3.67	1.34	50	11,100	61.6	53
	1/21/65	23,400	41.1	63.1	3.96	1.35	60.5	21,600	25.8	63
Johnstown Main	11/17/64	6,400	44.8	32.2	1.92	1.55	33.4	4,100	57.7	12.5
	12/3/64	15,000	27.5	42	3.60	1.46	49	18,400	42.0	45
	12/1/65	13,000	43.2	36.9	2.58	1.33	39.5	12,800	37.0	37
Tynville	11/17/64	102.4	25.4	0.53	0.0449	1.24	0.6	32.9	56	
	12/3/64	223	25.2	1.4	0.0809	0.925	1	213	17.9	2.0
Totals	11/17/64	19,852			5.7649			31,683		
	12/3/64	28,573			7.3509			29,713		
	1/21/65	37,000			6.54			34,400		

<sup>a</sup>The peak period was assumed 6.00 a.m. to 12 noon.

TABLE 10.17  
Composite Analyses (24 Hours) of Gloversville and Johnstown Wastewater

<i>Characteristic</i>	<i>February 18–19, 1965</i>		<i>March 30, 1965</i>		<i>April 21, 1965</i>		<i>May 6, 1965</i>	
	<i>Gloversville</i>	<i>Johnstown<sup>a</sup></i>	<i>Gloversville</i>	<i>Johnstown</i>	<i>Gloversville</i>	<i>Johnstown</i>	<i>Gloversville</i>	<i>Johnstown</i>
Flow, mgd	3.41	3.05						
24-hr average			3.05	4.88	3.63	2.84	4.3	2.07
6 a.m. to 12 noon average			4.73	6.33	4.29	3.00		
6 a.m. to 2 p.m. average								
pH	9.4	8.3					5.9	2.92
Total solids, ppm	3130	2450	2430	1970	2542	1840	3120	2962
Suspended solids, ppm	258	81	265	145	418	213	475	322
Volatile suspended solids, ppm			196	96	265	135	305	250
BOD (5-day, 20°C), ppm	405	385	300–435	285–330	371–435	371–386	485–520	540–585
BOD, lb/day	11,500	9800	(367) <sup>b</sup>	(307)	(403)	(378)	(502)	(562)
Settleable solids, ml/L			20.0	5.5	13.0	4.5	14.0	16.0
On supernatant			97	70	128	86	172	135
Suspended solids, ppm			78	52	92	60	120	110
Volatile solids, ppm			95–180	225–355	266–281	326–386	210–300	375–405
BOD, ppm			(285–330)					

TABLE 10.17 (continued)  
 Composite Analyses (24 Hours) of Gloversville and Johnstown Wastewater

Characteristic	February 18–19, 1965		March 30, 1965		April 21, 1965		May 6, 1965	
	Gloversville	Johnstown <sup>a</sup>	Gloversville	Johnstown	Gloversville	Johnstown	Gloversville	Johnstown
8-hr readings							690	423
Suspended solids, ppm							420	310
Volatile solids, ppm							405–495	405–435
BOD, ppm							(450)	(420)
Total ash, ppm	2250	1570						
Total volatile, ppm	880	880						
Suspended ash, ppm	140	48						
Suspended volatile solids, ppm	118	33						
Suspended volatile solids, %	46	41						
<i>Analysis of settled 2-hr sludge</i>								
Total solids, %	1.54	0.88						
Total ash, %	34.4	37.5						
Total organics, %	63.6	62.5						

<sup>a</sup>30-inch sewer.

<sup>b</sup>Average values are given in parentheses.

about 12 hours during the daytime. The pH becomes alkaline (8–10) during the same period but returns to normal (7–8) during the 12 night hours. The BOD varies considerably during both day and night but is generally high and is confined to a range of 300–700 ppm from 6 a.m. until midnight. There is little pattern of discharge of BOD and no apparent practical gain as far as BOD is concerned from separate equalization basins. Because the flow and pH are largely higher during the entire daytime period, equalization to level out these factors would require very large basins. The cost of such units and the potential danger of septicity seem, to the author, to far outweigh the benefits derived from leveling the flow and pH. In this instance, it seems that the great numbers of varied tanneries themselves contribute to equalization of waste simply by their diversity.

2. *The total BOD loads and flows* given in Tables 10.16 and 10.17 can be examined more easily by referring to Table 10.18. The total flow measured averages 6.724 million gallons per day (mgd) and contains an average of 23,442 lb of 5-day 20°C BOD and approximately 20,650 lb of suspended solids. These values do not include any flows or loads not connected to the Gloversville sewage treatment plant or the 30-in. sewer outfall in Johnstown. The 8-in. sewer outfall in Johnstown, though measured and sampled at the beginning, contains less than 1% of the total volume or BOD load and can, therefore, be considered insignificant in these surveys.
3. *The maximum variations in flow and load* from day to day were found to be 18% from the average flow and 22% from the average BOD. These variations are considered well within normal values and tend to substantiate the use of average daily values given under the previous section in designing waste-treatment facilities.

TABLE 10.18  
Summary of Total Loads for Treatment

<i>Date</i>	<i>Total flow, mgd</i>	<i>Total BOD, lb/day</i>	<i>Total Suspended Solids, lb/day</i>
11/17/64	5.765	19,852	31,683
12/3/64	7.351	28,573	29,713
1/21/65 <sup>a</sup>	6.540	37,000	34,400
2/18/65	6.460	21,300	9,405
3/30/65	7.930	21,925	12,700
4/21/65	6.470	21,150	17,700
5/6/65	6.370	27,850	22,700
Average	6.724	23,442	20,650

<sup>a</sup>Since an unusually large percentage of deerskin was tanned, this day was not considered typical of even maximum normal operation, and therefore, it was excluded from the average.

Industrial production records during the sampling days (Tables 10.19 and 10.20) demonstrated that all major industries connected to the two major sewer systems were in operation at almost full capacity during these days. This provides some measure of assurance in using the average flow and BOD values obtained during this period. Table 10.21 shows industry's percentage of the total measured flow on these days. This reveals an industrial waste problem of about 50% by volume when industry is operating near its rated capacity.

### Laboratory Pilot-Plant Studies

To form more definite conclusions on the proper units to be included in the waste-treatment plant, certain small-scale laboratory studies were necessary, including sludge digestion and activated-sludge treatment.

#### *Sludge Digestion*

A mixture of primary and secondary settled sludge was collected from the settling basins at the Gloversville treatment plant. A pilot digester, consisting of a glass container and a gas-collecting system maintained at 37°C, was set up in a private laboratory in Johnstown. The raw sludge sampled selected was analyzed for organic matter at the start of the "batch" digestion period and again after 50 days of digestion, and gas volume measured almost daily (Table 10.22).

Although this was a batch-type experiment, over the 50-day period, 9.07 ft<sup>3</sup> of gas was produced per pound of volatile matter destroyed. Greater amounts of gas may be expected from a continuous-digestion operation maintained at optimum environmental conditions. In this experiment, more gas would have evolved after an increased digestion period, but the rate of gas production did slow down considerably after 50 days. Normal gas production for sewage sludge is about 15 ft<sup>3</sup>/lb of organic matter destroyed. Digestion experiments on a continuous basis and over a longer period would be needed to assess whether an accumulated toxic effect exists. However, Vrooman and Ehle (1950) reported successful digestion of this waste sludge.

#### *Activated-Sludge Treatment*

The apparatus used in the study consisted of an aeration tank with two mixers and three separate air-diffuser tubes fitted with porous stones. Air flow (cubic feet of air per hour) was measured by a previously calibrated rotameter. The tank was 23.5 in. long and 8.5 in. wide and was filled to a depth that gave an aeration volume of 6 gallons.

Because settling was expected to be an integral part of a biological treatment plant of this type, various mixtures of settled tannery waste (1:1 mixture of beam-house and tan-yard wastes) and settled domestic sewage were added to the aeration tank in a semi-batch procedure to simulate continuous operation as closely as possible. The standard average aeration period of 6 hours was used and the waste mixture was added in three increments of 2 gallons each at 2-hour intervals. The tank contents (6 gallons of a mixture of tannery wastes and domestic sewage) were first settled for 1 hour. Then 2 gallons of the supernatant were siphoned off and 2 gallons of the waste mixture

TABLE 10.19  
Industrial Production during Sampling Days

Company	November 17, 1964		December 3, 1964		January 21, 1965	
	Water Used, gpd	% Production <sup>a</sup>	Water Used, gpd	% Production	Water Used, gpd	% Production
Wood and Hyde Leather	200,000	100	225,000	100	225,000	100
Filmer Leather	41,310	50	41,310	50	41,300	50
Twin City Leather	120,000	50	120,000	100	120,000	100
Wilson Tanning	49,920	80	54,337	80	38,000	50
Leavitt-Berner Tanning	151,700	100	151,700	100	151,700	100
F. Rulison & Sons	76,300	100	76,300	100	76,300	100
Peerless Tanning	24,000	33 ⅓	48,000	66 ⅔	48,000	66 ⅔
Karg Bros.	266,000	68	254,000	65	386,000	90-95
Decca Records <sup>b</sup>	10,807	100	10,807	100	10,807	100
U.S. Rabbitt Tanning Co. <sup>b</sup>	10,000	100	7,000	75	7,000	75
Gloversville Continental Mill <sup>b</sup>	200,000	66	190,000	100	190,000	100
Independent Leather	134,000	60	107,000	40	161,000	60
Liberty Dressing	78,950	70-75			120,803	60
G. Levor		80		80		
Framglo Tanners (1)	500,000	100	500,000	100	500,000	100
Framglo Tanners (2)		80		80		80
Rebel Dye <sup>b</sup>	26,250	10	30,500	10	24,500	9
Lee Dyeing <sup>b</sup> (Johnstown)	175,000	40	1,000	0	1,000	0
Adirondack Finishing <sup>b</sup>	450,000	80	450,000	80	500,000	90
Crown Finishing (Maranco Leather)	42,352	100	42,000	100	42,352	100

TABLE 10.19 (continued)  
 Industrial Production during Sampling Days

<i>Company</i>	<i>November 17, 1964</i>		<i>December 3, 1964</i>		<i>January 21, 1965</i>	
	<i>Water Used, gpd</i>	<i>% Production<sup>a</sup></i>	<i>Water Used, gpd</i>	<i>% Production</i>	<i>Water Used, gpd</i>	<i>% Production</i>
Simco Leather	61,300	100	61,000	100	61,000	100
Johnstown Tanning	60,000	70	35,000	60	10,000	40
Napatan	21,072	100	21,000	80	21,000	100
Ellithorp Tanning	105,000	100	110,000	100	110,000	100
Johnstown Knitting <sup>b</sup>			100,000	45	100,000	75
Gloversville Leather						
Riss Tanning						
Industrial total, gpd	2,803,961		2,735,954		2,845,662	
Total flow, mgd	5.7649		7.3509		6.54	
Total BOD, lb/day	19,852		28,573		37,000	
Industrial portion of total water flow, %	48.7		37.2		43.4	

<sup>a</sup>Percentage of plant's total productive capacity.

<sup>b</sup>Figures are based on yearly consumption (average figure).

TABLE 10.20  
Water Consumption Related to Production Percentage<sup>a</sup>

<i>Industry</i>	<i>Water Consumption, gal</i>		<i>Production Percentage</i>				
			<i>Beamhouse</i>		<i>Tanning</i>		
	<i>From Meter Reading</i>	<i>From Other Sources</i>	<i>Type of Skin</i>	<i>Rated Potential</i>	<i>Compared 1/21/65</i>	<i>Operation Potential</i>	<i>Type</i>
Leather tanneries							
Wood and Hyde Leather	150,000	75,000	Burn—sheep	100	100	100	Combination
Filmer Leather	90,000	Pond (in future)	Horse, cow, jacks, deer	100	75	80	Combination
Twin City Leather	10,028		Sheep	100	100	100	Combination
Wilson Tanning	25,215		Sheep, goat, deer	0	0	33½	Combination
Leavitt-Berner Tanning (not contributing to sewage treatment plant)	140,000		Sheep, goat, deer	100	100	100	Combination
F. Rulison & Sons	60,150		Horse, cow	80	80	80	Combination
Peerless Tanning	21,766					75	Chrome
Karg Bros.	400,000		Pig, deer	100	100	100	Chrome
Independent Leather	230,000					100	Combination
Liberty Dressing	85,582		Goat, calf			45	Combination
G. Levor	Drinking water only	600,000	Pig, calf, goat	80		80	Combination
Framglo Tanners (1)	Drinking water only	400,000	Sheep, deer			100	
Framglo Tanners (2)	Drinking water only	300,000		80		None	
Crown Finishing (Maranco Leather)	26,465					100	Chrome, some combination and vegetable
Simco Leather	45,030						
Johnstown Tanning (1)	11,000					10	
(2)	0						

TABLE 10.20 (continued)  
Water Consumption Related to Production Percentage<sup>a</sup>

Industry	Water Consumption, gal		Production Percentage				
			Beamhouse		Tanning		
	From Meter Reading	From Other Sources	Type of Skin	Rated Potential	Compared 1/21/65	Operation Potential	Type
Ellithorp Tanning	248,000	From Levor				90	Chrome and combination
Gloversville Leather	0	152,000				25	Chrome and combination
Riss Tanning	27,970					33½	Chrome and combination
Nonleather industries							
Rebel Dye	61,000 (8,145 ft <sup>3</sup> )		20				
Adirondack Finishing	474,310		80				
Lee Dyeing	8,800 (1,175 ft <sup>3</sup> )		0				
(Johnstown) Gloversville Continental Mill	208,000 gal		66 ⅔		Anticipate 330,000 gal due to dyeing technique but not necessarily increased production		
Johnstown Knitting	150,200 (20,178 ft <sup>3</sup> )		75				
Diane Knitting	10,590 ft <sup>3</sup>		75				
Decca Records	17,745 (2,366 ft <sup>3</sup> )		75				
Mohawk Cabinet			80				
U.S. Rabbitt Tanning Co	1,000		0		Water running in tubs to keep them soaked. Should be disregarded		
Total industrial flow, gal	4,019,262						
Total flow, gal	6,460,000						
Total BOD	21,300 lb/day						
Industrial flow (% of total)	62.5%						

<sup>a</sup>Data are for the 24 hour period from 6 a.m. on February 18 to 6 a.m. on February 19, 1965.

TABLE 10.21  
Industrial Waste Flow

<i>Date</i>	<i>Total Flow, mgd</i>	<i>Industrial Flow (Estimated by Survey), mgd</i>	<i>Industrial Portion of Total Flow, %</i>
11/17/64	5.765	2.804	48.7
13/3/64	7.351	2.736	37.2
1/21/65	6.540	2.846	43.4
2/18/65	6.460	4.019	62.5
Average			ca.48

added. The tank contents were aerated for 2 hours and settled for 15 minutes, 2 gallons of supernatant were withdrawn, and 2 more gallons of waste mixture added. This procedure resulted in the addition of 6 gallons of waste mixture in a period of 4 hours, for a total aeration time of 8 hours and an average aeration period of 6 hours, as shown below:

<i>Time, hr</i>	<i>Volume Added, gal</i>	<i>Aeration Time, hr</i>
0	2	8
2	2	6
4	2	4
		Average: 6

The results obtained are summarized in Table 10.23 and shown graphically in Figure 10.10. Each loading represents about 1 week of aeration data with samples being taken for analysis several times during this week of adaptation and acclimation.

Laboratory experiments verified that 65–75% of this waste would degrade biologically even when loaded at the high rate of 95–115 lb BOD/1,000 ft<sup>3</sup> of aerator (see Figure 10.10). Higher BOD reductions (75–85%) were obtained with lower BOD loadings (60–82 lb/1,000 ft<sup>3</sup>) and increased dilution of the tannery waste with domestic sewage.

These studies showed that the activated-sludge process or a modification of it could be used successfully in the overall treatment of the combined tannery and sewage wastes. Larger prototype field experiments would disclose whether these results can be projected directly to full-scale operation.

The present Gloversville treatment plant has experienced much difficulty because of its overloaded condition. However, from the best records available, when all the flow units of the plant were operating, about 58–60% of the BOD was removed. This reduction in BOD also shows that biological degradation by trickling filtration is possible with

TABLE 10.22  
Sludge Digestion (Laboratory Study)<sup>a</sup>

<i>Accumulated Gas Produced, cc</i>	<i>Days of Digestion at 37°C</i>
250	1
290	2
460	3
640	4
730	5
850	6
940	7
990	8
1,040	9
1,140	10
1,140	11
1,150	12
1,190	13
1,240	14
1,290	15
1,340	16
1,380	17
1,420	18
1,480	19
1,540	20
1,600	21
1,650	22
1,700	23
1,820	24
1,900	25
1,940	26
1,980	27
1,980	28
2,010	29
2,020	30
2,030	33
2,040	36
2,050	40
2,170	49
2,200	50

<sup>a</sup>The results were analyzed as follows:

organic matter (raw sludge)	= 5.4533 gm
organic matter (after 50 days)	= 1.5542 gm
loss of organic matter	= 3.8991 gm (71.2%)
gas produced:	total = 2,200 cc
per gram of organic matter destroyed	= 567 cc
per gram of volatile matter added	= 403 cc

To convert results from the metric system:

$2,200 \times 0.000353$	= 0.0777 ft <sup>3</sup> of gas produced (total)
$\frac{3.8991}{454}$	= 0.00858 lb of volatile (organic) matter destroyed
$\frac{0.00777}{0.00858}$	= 9.07 ft <sup>3</sup> of gas per pound of organic matter destroyed

TABLE 10.23  
Activated-Sludge Pilot Laboratory Studies

<i>Waste Treated</i>		<i>BOD</i>					
<i>Origin</i>	<i>Quantity, gal</i>	<i>BOD Loading, lb/1,000 ft<sup>3</sup></i>	<i>Suspended Solids Under Aeration, ppm</i>	<i>Air rate, ft<sup>3</sup>/lb BOD Removed</i>	<i>Influent, ppm</i>	<i>Effluent, ppm</i>	<i>Reduction, %</i>
Sewage	5						
+ tannery waste mixture	1	60	2,330	2,450	239	44	81.6
Sewage	4						
+ tannery waste mixture	2	82.8	2,221	1,900	331	78	76.5
Sewage	3						
+ tannery waste mixture	3	114.7	2,768	1,735	459	165	64.1
Sewage wastes							
Gloversville	5						
Johnstown	1	70	3,386	2,000	280	39	86
Sewage wastes							
Gloversville	4.015						
Johnstown no. 1	2.112						
Johnstown no. 2	0.044	73.8	2,508	2,116	295	68	76.9
Tannery waste mixture	3						
+ tap water	3	93.0	2,646	1,070	374	91	75.6

this waste under full-scale field conditions. The exact degree of this oxidation could be determined more easily in a properly designed and operated field pilot plant.

### Literature Survey

A study was also made of previous research work or reported practice dealing with combined treatment of domestic sewage and tannery waste by the activated-sludge process. The reports of Chase and Kahn (1955), Braunschweig (1965), Jansky (1961), Thebaraj et al. (1962), Snock (1928), Hubbel (1935), Pauschardt and Furkert (1936), Kubelka (1952, 1956), Fales (1928), Kalibina (1931), Furkert (1937), and Mausner (1938) provide some evidence that the activated-sludge treatment process is feasible for tannery-sewage waste mixtures. This review of previous work tends to substantiate the biological pilot studies described earlier. Most of this reported work, however, has been on a research or pilot-plant basis or of a more sewage-diluted waste. There is a definite

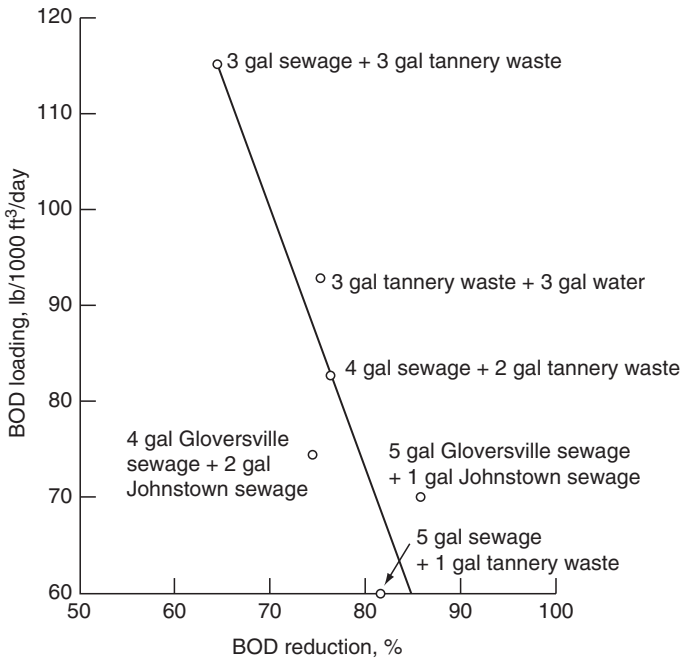


FIGURE 10.10. Activated-sludge treatment: BOD reduction related to BOD loading. (From Nemerow 1987.)

lack of reviews of full-scale biological treatment used on tannery and sewage waste mixed 50:50 (by volume).

Braunschweig (1965) disproves the notion that chromium in the newer tannery processes interferes with aerobic biological treatment. The work by Jansky (1961) is typical of that of the supporters of activated sludge as a treatment method. Thebaraj et al. (1962) found that all aerobic biological systems were effective and that the choice depended on several economic and practical considerations. Fales (1928), much earlier, was of the same opinion as Thebaraj but pointed out the higher operating costs of activated sludge compared to trickling filtration. Furkert (1937) also verifies our digestion studies and noted that except for the high H<sub>2</sub>S content of the digester gas, the composition of the gas is normal.

### Conclusions from Study

The following specific conclusions and recommendations were made as a result of this study:

1. The stream survey was instrumental in providing evidence that secondary treatment of the combined industrial and sanitary wastes of the area were required and that 65–94% BOD reduction would be needed depending on the dilution

available in the stream. Use of the curves plotted in Figures 10.8 and 10.9 would allow for a more precise selection of BOD reduction required for specific critical stream flows.

2. The existing dry-weather flow to be treated averages 6.724 mgd with peaks of two to three times this rate; about 50% of this flow originates from the industries in the area.
3. The combined area waste contains a daily average of 23,442 lb of 5-day 20°C BOD and 20,650 lb of suspended solids. These loadings are affected considerably by the type of skin tanned, deer skin being an especially significant contributor of high BOD and solids loads.
4. Laboratory pilot studies demonstrated that the conventional activated-sludge treatment process is capable of reducing the BOD of the combined waste from 65 to 85% (depending primarily on the organic loading) at loadings ranging from 60 to 115 lb BOD/1,000 ft<sup>3</sup> of aerator capacity.
5. A digestion batch experiment yielded about 9 ft<sup>3</sup> of gas per pound of volatile matter destroyed and effected a 71% reduction in organic matter.
6. A literature survey confirmed the findings of the laboratory results that is the combined wastes of this type are amenable to biological oxidation.
7. Because of the unique nature of the volume and characteristics of the tannery–sewage waste mixture, as well as the size and cost of the project, field prototype studies preceded full-scale plant construction.
8. There should be additional laboratory research on development of improved methods of aerobic biological treatment of tannery wastes to allow for greater BOD reduction at higher BOD loadings.

The decision reached as a result of this study was that the cost was too high, the risk too great, and previous reported experience inadequate for full-scale biological treatment to be recommended. A prototype in the field—preferably at the site of the Gloversville treatment plant—was to be built and operated for about 6 months to obtain greater certainty that the earlier findings were valid. This prototype should contain both trickling-filtration and activated-sludge units (as well as provision for its modification). It should also allow for experimentation with series and parallel operation of the units and both diffused and mechanical aeration. Some sludge-digestion studies should be carried out over the entire period.

A schematic drawing of this field prototype is shown in Figure 10.11. It consists of two sets of screens in series ( $\frac{1}{2}$ -in. openings followed by  $\frac{1}{4}$ -in. openings), pump, primary settling, trickling filter, aeration, and final settling. The plant began operation in early August 1965 and sampling was begun on August 16. Table 10.24 gives data for the first 7 weeks of operation. Table 10.25 shows how the prototype operating results influenced the final design parameters.

### Overall Planning Study Conclusions

The conclusions reached through data collection, pilot and prototype plant studies, engineering evaluations, and reviews of design and operational experiences in major

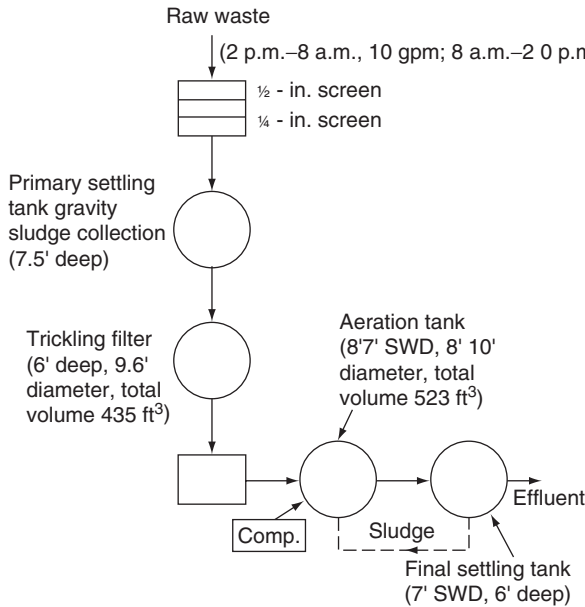


FIGURE 10.11. Field prototype of the Groversville–Johnstown joint treatment plant. (From Nemerow 1987.)

municipal sewage-treatment plants treating large amounts of tannery waste may be summarized as follows:

1. *Degree of treatment.* Primary treatment by settling, followed by secondary treatment through biological processes, is required to meet New York State standards for plant effluent quality that may be accepted by the Cayadutta Creek under conditions of minimum dissolved oxygen content (at times of low flow and high temperature). The efficiency of treatment units and processes must be high, with an overall plant removal of approximately 85% of the incoming BOD.
2. *Pretreatment at mills.*
  - a. Tanneries should remove fleshings, hair, hide pieces, and trimmings to make discharges transportable in gravity sewers. This can be accomplished by means found most efficient and economical, including primary settling tanks and/or mechanical screening. Animal greases plus petroleum solvents should be removed at the tanneries.
  - b. The glue factory should remove settleable solids to make discharges transportable in gravity sewers. This can be accomplished by means found most efficient and economical, including primary settling tanks and/or mechanical screening.
3. *Sewage-treatment plant: processes (general).* The liquid wastes treatment will include pretreatment by mechanical screening, grit removal, pre-aeration of

TABLE 10.24  
 Prototype Operating Data

Date	Raw Waste			Primary Effluent			Trickling-Filter Effluent			Final Effluent			Under Aeration	
	BOD, ppm	pH	SS, ppm	BOD, ppm	pH	SS, ppm	BOD, ppm	pH	SS, ppm	BOD, ppm	pH	SS, ppm	SS, ppm	pH
8/16/65	655	7.6	603	448	7.3	248	353	7.3	251	93	7.2	139	1,430	7.2
8/17/65	468	8.4	528	373	8.3	256	241	7.6	202	81	7.2	44	1,603	7.3
8/18/65	468	9.1	578	380	9.0	170	230	8.5	262	73	7.4	75		
8/19/65	563	8.0	369	390	8.0	211	268	7.6	187	85	7.2	78	1,850	7.3
8/20/65	493	8.5		408	8.7	281	256	8.3	166	73	7.4	84	2,631	7.6
8/23/65	443	7.0	382	433	7.4	145	316	7.5	243	72	7.5	43	2,313	7.4
8/24/65	555	8.1	393	425	8.1	184	330	7.8	250	90	7.4	89	2,066	7.5
8/25/65	370	7.9	392	313	7.8	169	398	7.8	394	79	7.4	197	2,487	7.5
8/26/65	408	8.3	454	360	7.8	243	231	7.5	168	102	7.3	127	2,788	7.2
8/27/65	273	8.8	337	308	8.5	135	215	8.1	155	19	7.6	53		
8/30/65	298	7.9	347	210	8.1	111	124	7.5	116	25	7.4	47	1,848	7.6
8/31/65	250	7.9	379	230	7.9	230	163	7.8	214	24	7.5	67	1,934	7.4
9/1/65	423	7.8	460	260	7.9	292	256	7.8	260	54	7.5	160	854	7.6
9/2/65	483	8.6	550	408	8.4	350	435	8.4	360	96	7.5	166	2,243	7.8
9/3/65	455	7.9	431	315	7.9	311	235	8.0	205	141	7.5	216	2,775	7.6
9/9/65	563	8.1	486	418	8.2	82	275	7.9	87	76	7.4	264	2,430	7.9
9/10/65	563	7.9	262	413	7.4	110	290	7.4	137	51	7.1	218	2,500	7.4
9/13/65	563	8.4	329	453	8.1	154	290	8.2	142	112	7.4	180	2,219	7.6
9/14/65	628	8.7	392	538	8.6	240	351	7.6	210	162	7.4	366	1,899	7.4
9/15/65	658	7.6	356	568	7.6	257	349	7.5	178	69	7.0	22	2,653	7.2
9/16/65	623	9.0	235	593	8.5	108	368	8.5	105	62	7.5	19	3,025	7.6
9/17/65	635	7.6	284	460	7.6	60	348	7.5	96	75	7.1	44	3,226	7.5
9/21/65	720	7.9	425	425	7.8	199	215	7.6	178	135	7.4	130	2,300	7.5
9/22/65	530	7.2	435	450	7.0	167	204	7.0	166	55	7.0	338	2,892	6.9
9/23/65	490	8.0	349	393	8.0	173	183	7.6	224	33	7.3	51	2,790	7.5
9/24/65	730	8.7	288	523	8.5	192	170	8.3	115	111	7.5	140	2,490	7.8
9/27/65	543	8.5	306	383	8.4	247	233	7.8	240	117	7.4	93	2,326	7.6
9/28/65	480	8.1	403	420	8.0	197	289	7.8	193	127	7.6	124	2,361	7.8
9/29/65	516		315	463		177	258		180	126		141	2,664	
9/30/65	650	8.1	307	490	7.6	145	344	7.5	195	192	7.4	157	2,096	7.4
10/1/65	435	7.8	312	363	7.6	162	280	7.6	229	158	7.2	241	1,495	7.4

SS, suspended solids.

TABLE 10.25  
 Prototype Operating Results and Design Parameters

<i>Unit and Effect</i>	<i>Prototype Results<sup>a</sup></i>	<i>Design Parameters</i>	<i>Comment</i>
Primary settling tank			Prototype tank construction and inherent limitations in small tanks resulted in lower settling efficiencies. Better results are expected in full-scale tanks with scum- and sludge-removal facilities and improved hydraulic characteristics. Additional settling-tank efficiency could be obtained by using flocculating agents if needed.
Suspended solids removal, %	49 (75) <sup>a</sup>	60	
Surface settling rate	390 (330)	800	
5-day BOD removal	24 (39)	30	
Roughing filter, with loading of 150 lb of BOD <sub>5</sub> /1,000 ft <sup>3</sup>	33% BOD <sub>5</sub> removal	30% BOD <sub>5</sub> removal	Performance of roughing filter established by test.
Aeration tank	81% BOD <sub>5</sub> removal	81% BOD <sub>5</sub> removal	Performance of activated sludge system established by test.
Process loading of 0.26 lb BOD/lb MLSS (8-hr peak)			
Process loading of 0.4 lb BOD/lb MLSS (24-hr average)	77% BOD <sub>5</sub> removal	77% BOD <sub>5</sub> removal	
Aeration tank (oxygen requirements, lb/day)	0.7 lb BOD <sub>SR</sub> + 0.02 lb MLSS	1 lb O <sub>2</sub> /lb BOD <sub>5</sub> removed/day)	Aerator capacity designed for mean peak 8-hr BOD loading with 25% present safety factor. Oxygen transfer ratio, $\alpha$ , to be determined in laboratory prior to final specifications on aerators.
Secondary settling tanks, surface settling rate (gal/ft <sup>2</sup> /day)	760 gal/ft <sup>2</sup> /day	600 gal/ft <sup>2</sup> /day (at peak 8-hr rate of 13.1 mgd)	Selection of design overflow rates not on basis of pilot plant results. Inclusion of skimming devices on secondary settling tanks due to experience with pilot plant.
Flotation (thickening of waste-activated sludge)	Waste sludge of less than 0.5%. Solids thickened to 5% or greater at loadings greater than 2 lb/ft <sup>2</sup> /hr	Design loading: 2 lb/ft <sup>2</sup> /hr	Review of prototype data indicates that the design loading is suitable and that this loading should be achieved without the use of chemical conditioning.
Sludge digestion tank	Digestion studies did not develop digestion rate curves	Displacement time Primary, 25 days Secondary, 25 days	Digestion studies were not conclusive.

MLSS, mixed liquor suspended solids. <sup>a</sup>The data in parentheses give the results achieved by using polymer.

grease for removal in primary treatment, and pretreatment for pH control and chemical coagulation (in future); primary treatment by settling; and secondary treatment by trickling filters (high-rate roughing filters), then through activated sludge, followed by settling, with provisions for chemical precipitation for more complete solids removal in the future, with discharge to Cayadutta Creek where further treatment is by dilution and the oxygenation capacity of the stream.

Sludge treatment and disposal will include high-rate digestion with sludge-gas utilization followed by de-watering by lagoons and disposal by approved landfill methods; de-watering by vacuum filters and disposal by approved landfill methods; or de-watering by vacuum filters, incineration (multiple hearth), and disposal of ash by landfill.

4. *Sewage treatment plant: processes (recommendations)*. The following treatment units and processes are specifically recommended and should be included in preliminary planning:
  - a. Three mechanically cleaned barrack screens to remove large debris from the flow
  - b. Two circular grit-removal units designed on surface overflow rate to remove grit and sand before primary settling (separation and washing of settled grit and organic matter by two hydrocyclone classifying devices). Before final design, consideration to be given to utilization of an aerated grit-removal unit
  - c. Disposal of screenings and grit in sanitary landfill
  - d. Grease removal by skimming in the primary settling tanks; grease flotation facilitated by aeration following or incorporated with grit-removal unit and immediately preceding the primary settling tanks
  - e. Possible future chemical application in the aeration structure for pH control and introduction of chemicals to aid precipitation of wastes, for short periods, at times of exceptionally low flows in Cayadutta Creek
  - f. Possible future addition of coagulating chemicals in the flow to the secondary clarifiers for "polishing" effluent and/or in the discharge from the secondary clarifiers for control of algal nutrients, if found necessary (structure provided for addition of coagulating chemicals in inflow)
  - g. Six rectangular primary settling tanks with mechanical sludge collectors and scum skimmers
  - h. Biological secondary treatment in two stages by two high-rate (roughing) filters, with stone or plastic media and rotating arm distributors, and activated-sludge treatment (in multiple units) in two sections, with mechanical aeration units directly powered by electric motors
  - i. Two circular secondary settling tanks with sludge- and scum-collection mechanisms, sludge collectors to be of the "vacuum cleaner" type
  - j. High-rate digestion provided through a primary digester followed by a secondary digester; floating covers on both digesters with gas-collection and holder facilities; gas utilization for heating of sludge and buildings; gas recirculation mixing provided in both digesters, with possible operation of either digester as primary

- k. De-watering of digested sludge and disposal of sludge cake by approved landfill methods

Final recommendations and determinations on sludge de-watering and disposal must consider net annual costs, reflecting capital costs and operation, the physical problems involved in handling sludge as amounts increase over the years, and the future utilization of the land considered for landfill. Certain inferences of these evaluations can be made from the engineering and cost points of view. However, the Cities of Gloversville and Johnstown and the Town of Johnstown, as well as the New York State Department of Health, must also consider future land use and future disposal of both sewage-treatment plant wastes and municipal refuse. As a guide in the financial comparisons, the following is an estimate of the approximate net annual costs (capital plus operational) for the three possible methods:

A. De-watering by lagoons and disposal by approved landfill methods	\$20,000
B. De-watering by vacuum filters and disposal by approved landfill methods	\$50,000
C. De-watering by vacuum filters, incineration (multiple hearth), and disposal of ash by landfill	\$65,000

De-watering at Fond du Lac, Wisconsin, was formerly achieved by vacuum filters. To reduce high de-watering costs, vacuum filtration was abandoned and replaced by evaporation and drainage in lagoons. De-watered sludge removed from the lagoons is disposed of in landfill. This technique has been in operation since 1962. Sewage-treatment plant loadings at Fond du Lac are only slightly less than those anticipated in the Gloversville–Johnstown design (6.4 mgd including 3 mgd of tannery wastes). Fond du Lac suspended solids are 173,000 lb/wk (compared to Gloversville–Johnstown at 195,578 lb/wk).

Based on the previous operational experience and consideration of the low annual costs compared to de-watering by vacuum filtration, de-watering by lagooning is recommended. In accordance with the requirements of the New York State Department of Health, the alternative to de-watering of the digested sludge by lagooning would be de-watering by vacuum filtration. For both methods, ultimate disposal would be by landfill. Both primary and secondary treatment units are shown schematically in Figure 10.12 and in a general view in Figure 10.13.

### Solids Handling

The estimated quantity of raw solids to be handled at the plant is 170,000 lb/wk, of which approximately 70% is of industrial origin, primarily tannery wastes.

A review of existing secondary wastewater treatment plants in the United States and Canada handling a large percentage of solids disclosed four plants that were treating tannery effluents in combination with municipal wastewaters. All four plants use digestion. To dispose of the digested solids in liquid form on wastelands using tank

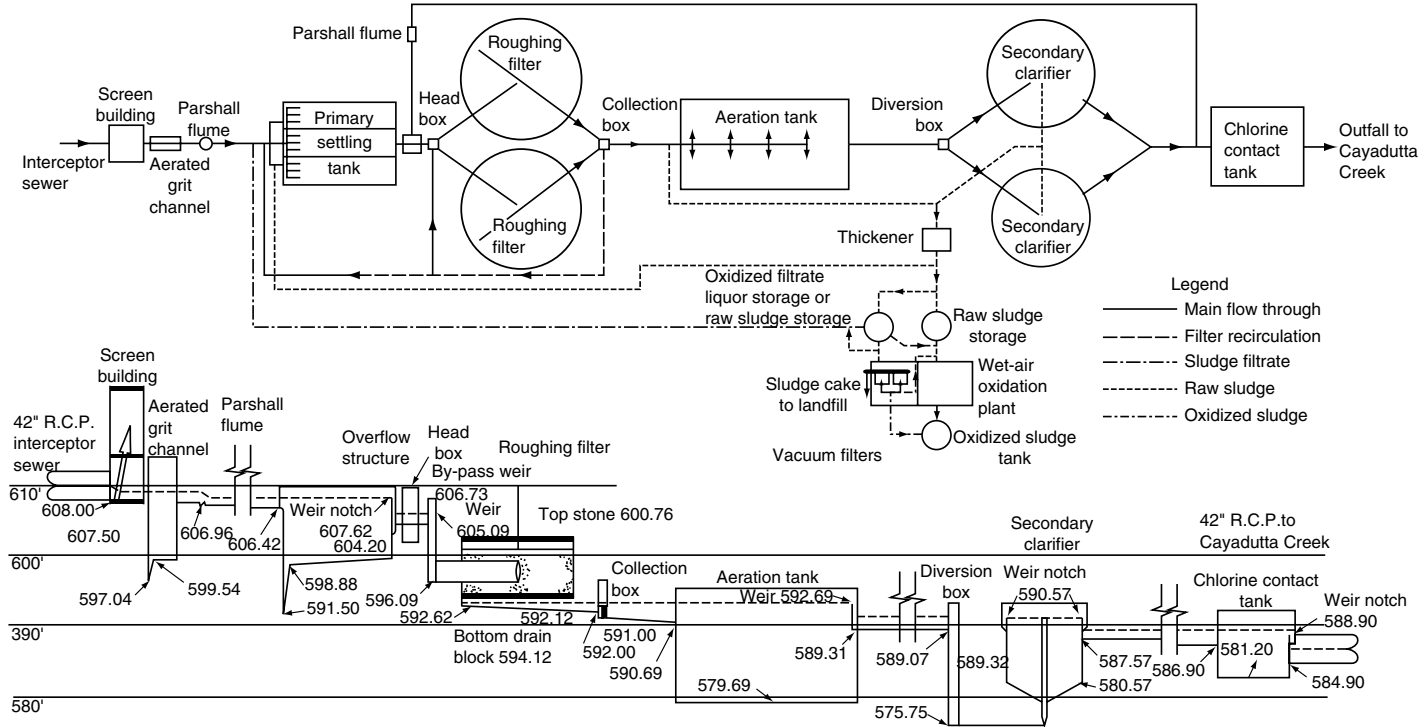


FIGURE 10.12. Line diagram and hydraulic profile of the Gloversville-Johnstown joint waste-water treatment plant. (Courtesy Morrell Vrooman Engineers.)

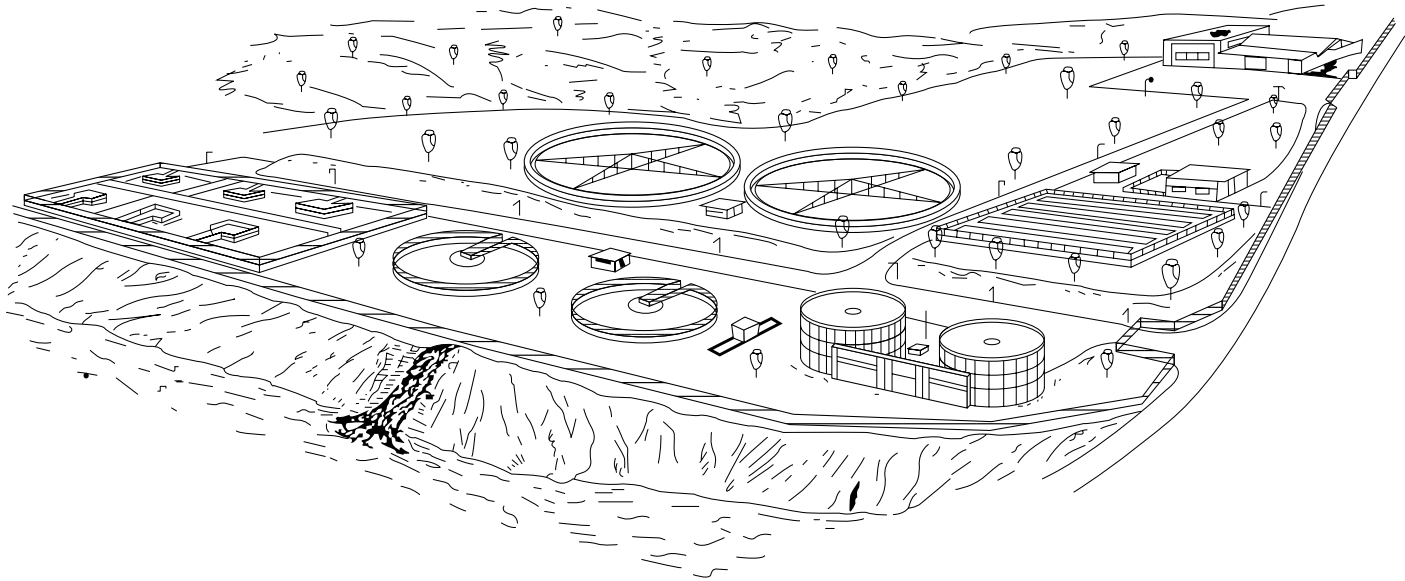


FIGURE 10.13. General view of the Gloversville–Johnstown joint treatment plant. (Courtesy Morrell Vrooman Engineers.)

trucks, one lagoons the digested solids, and one uses vacuum filtration, drying, and landfill. All of the plants are able to digest the solids effectively.

The problems with digestion of tannery-municipal solids have not been primarily chemical or biological but physical. Hair and scum have caused serious problems in the digesters themselves and in digestion-tank appurtenances. Extensive pretreatment, including fine screens, have been necessary at some plants to reduce such problems. The screens have in some cases introduced another problem, blinding.

The cities of Gloversville and Johnstown are surrounded by a rural area providing land for landfill of the final residue from the sludge-handling system. Both cities operate refuse landfills and own large areas of land designated for future landfill use. Therefore, landfill of the de-watered solids from the wastewater treatment plant could be accomplished.

A review of construction and operational costs indicated that digestion and de-watering in lagoons would provide the most economical solution to conditioning the solids. This solution was discussed extensively with the regulatory agencies and with the Gloversville–Johnstown Joint Sewer Board, who have responsibility for administering the project, but was eventually eliminated.

There was considerable interest in the wet-air oxidation system being used to condition and destroy organic solids. This system was viewed as capable of treating industrial solids without possible upset by the changing chemistry of the leather industry. The Zimpro Division of the Sterling Drug Company had considerable experience in handling similar solids at South Milwaukee and in Kempen, Germany. The wet-air process offered the added advantage of producing a solid that was readily filterable. The filterability of either raw or digested solids has been a potentially troublesome and expensive feature of the operation.

The sludge-handling process finally selected was a low-pressure (300 psi), wet-air oxidation plant, vacuum filters for de-watering, and ultimate disposal of solids in landfill. The wet-air plant as designed will reduce the nonsoluble organic solids by 40–50%. The high BOD filtrate will be pumped to a holding tank and discharged to the head of the plant during low BOD load periods. This plant will have the capacity to handle the weekly solids loading in 5 days on a 16-hour schedule or in 3½ days on a 24-hour schedule. It is basically one unit with several key items of equipment duplicated. The two vacuum filters will de-water cake from the oxidized-sludge holding tank. This tank will be equipped with overflow weirs and a sludge collector. The dense sludge pulled from the tank will be filtered during the 8-hour day shift, 5 days per week. This solution to the sludge-handling problem is not conventional, but it addresses the unique problem of these particular communities in their location and with their industries.

## Final Design of the Gloversville–Johnstown Joint Sewage Treatment Plant

1. *Flow*

24-hr mean	9.50 mgd
8-hr mean peak	13.12 mgd

1-hr mean peak	16.22 mgd
1-hr maximum peak (to be used in hydraulic design of conduits)	19.3 mgd
Maximum hydraulic capacity through primary	30 mgd
2. <i>Process loading to sewage-treatment plant</i>	
BOD weekday 24-hr mean	35,019 lb/day
BOD weekday 8-hr mean	53,351 lb/day
Suspended-solids load	195,578 lb/week
3. <i>Mechanically cleaned bar screens</i>	
Number of units	3
Width of screen channel	3 ft
Bar spacing	1-in. clear opening
Velocity through screen at	
5.0 mgd	1.2 ft/sec
9.5 mgd	1.6 ft/sec
30 mgd	2.7 ft/sec
4. <i>Grit-removal units</i>	
Number of units	2
Type	Aerated
Dimensions	7 ft wide × 30 ft long × 7 ft deep
Particle size removed	100% of 0.2 mm at 20 mgd
Grit-cleaning devices (cyclone with screw classifier)	2 units
Grit disposal	Landfill
5. <i>Primary settling tanks</i>	
Number of tanks	6
Flows and surface settling rates	
8-hr peak (basic design)	13.12 mgd; 800 gal/ft <sup>2</sup> /day
24-hr	9.50 mgd; 580 gal/ft <sup>2</sup> /day
Maximum peak hour	19.3 mgd; 1,180 gal/ft <sup>2</sup> /day
Total surface area required	16,400 ft <sup>2</sup>
Surface area of each tank	2,736 ft <sup>2</sup>
Tank dimensions	152 ft long × 18 ft wide × 8 ft deep
Displacement time at	
13.12 mgd	1.8 hr
9.50 mgd	2.5 hr
Estimated removals	
Suspended solids	60%
5-day BOD	30%
6. <i>High-rate (roughing) filters</i>	
Number of units	2

Process loading:

Peak 8-hr BOD	150 lb/1,000 ft <sup>3</sup>
24-hr average BOD	98 lb/1,000 ft <sup>3</sup>
Diameter of filters	165 ft
Depth of filters	6 ft
Hydraulic loading	
8-hr peak	315 gal/ft <sup>2</sup> /day
24-hr average	227 gal/ft <sup>2</sup> /day
Volume of filter media	250,000 ft <sup>3</sup>
Filter media	4-in. stone or plastic
Recirculation pumps	3–3,500 gpm variable speed
Removal, 5-day BOD	30% at 150 lb/1,000 ft <sup>3</sup>

7. *Aeration tank and equipment*

Number of tanks	1 with 2 compartments
Volume division of each tank	¼ and ¾
Tank dimensions	260 ft long × 130 ft wide × 13 ft deep
Total tank volume	439,000 ft <sup>3</sup>
Process loading:	
24-hr average	0.25 lb BOD/lb
(39 lb/1,000 ft <sup>3</sup> )	MLSS at MLSS of 2,500 ppm
8-hr peak (60 lb/1,000 ft <sup>3</sup> )	0.39 lb BOD/lb MLSS at MLSS of 2,500 ppm
Displacement time including	
33% recirculation	
24-hr flow, 9.50 mgd	6.3 hr
8-hr flow, 13.12 mgd	4.5 hr
Aeration equipment	
Type	Mechanical
Number of aerators	8
Connected horsepower	800 hp
Aerator oxygenation capacity (each)	310 lb/hr

8. *Secondary settling tanks*

Number of tanks	2
Diameter	120 ft
Side water depth	10 ft
Surface settling rate	
13.12 mgd flow	600 gal/day/ft <sup>2</sup>
9.50 mgd flow	434 gal/day/ft <sup>2</sup>

9. *Chlorination equipment and contact tank*

Number of tanks	1 with 2 compartments
Dimensions	100 ft long × 60 ft wide (30 ft each) × 7 ft deep

Detention time at	
30 mgd	15 min
9.5 mgd	47 min
5.0 mgd	90 min
Chlorinators	
Number	2
Rating	4,000 ppd
Evaporators	
Number	2
Rating	4,000 ppd
Residual analyzer number	1
10. <i>Secondary return sludge pumps</i>	
Number of pumps	3
Type	Variable speed
Maximum capacity each	2,500 gpm
11. <i>Waste sludge pumps</i>	
Number of pumps	3
Type	Variable speed
Maximum capacity each	200 gpm
12. <i>Sludge thickener</i>	
Number of units	2
Type of thickener	Flotation
Loading	2 lb/ft <sup>2</sup> /hr
Operation	100 hr/wk
Total surface area required	264 ft <sup>2</sup>
Total surface area provided	300 ft <sup>2</sup>
13. <i>Wet-air oxidation unit</i>	
Number of units	1
Capacity	25 tons/day
Operating pressure	300 psig
Insoluble organic matter reduction	50%
Operating volume and schedules	
170,000 lb/wk	65% volatile content, 5% solids
24 hr/day continuous operation	3½ days/wk
16 hr/day operation	5 days/wk
Oxidized- sludge storage	120,000 gal for 1 day
Duplicate items	Boiler High-pressure pump
14. <i>Raw-sludge holding tanks</i>	
Number of tanks	2
Total holding capacity	7 days

Tank proportions	
Side water depth	20 ft
Diameter	42 ft

15. *Vacuum filtration*

Number of units	2
Filter area	400 ft <sup>2</sup> each
Design filter rate	
Oxidized sludge	5 lb/ft <sup>2</sup> /hr
Raw sludge	5 lb/ft <sup>2</sup> /hr
Operating volume and schedules	
Oxidized sludge, 115,000 lb/wk	29 hr filter time/wk
Raw sludge, 170,000 lb/wk	43 hr filter time/wk

16. *Ultimate disposal of oxidized filter cake*

Sludge to be landfill in city refuse areas or other selected areas. Because of the character of oxidized sludge cake, sludge need not be covered.

Estimated Costs and Financing

Estimated costs of the plant units described in the preceding list follow:

	Amount
Site development	\$300,000
Screen building and grit tanks	158,000
Primary settling tank	323,000
Roughing filters (two)	437,000
Aeration tank	645,000
Secondary settling tanks	310,000
Chlorine contact tank	67,000
Recirculation building	203,000
Overflow and Parshall flume structures	10,000
Sludge building, including thickeners, vacuum filters, and wet-air plant	1,056,000
Sludge and oxidized liquor holding tanks	77,000
Yard piping and conduits	279,000
Waterline to plant site and meter pit	32,000
Fencing	11,000
Administrations building	228,000
Electrical contract	250,000
<i>Subtotal</i>	<u>\$4,386,000</u>
Contingency (5%)	219,300
Total	<u>\$4,605,300</u>

The project costs and the federal and state grants are estimated as follows:

Interceptor sewers	\$1,227,000
Wastewater treatment plant	<u>4,600,000</u>
<i>Subtotal</i>	5,827,000
All other costs and contingencies	<u>1,212,000</u>
Total	7,039,000
Less federal and state grants	<u>3,981,000</u>
Net cost to community	3,058,000

It is estimated that the plant will have 20 full-time employees and that the annual operational and maintenance costs will be \$262,000. The local communities will receive a reimbursement from the State of New York to the amount of one-third of this cost, leaving a local net cost of \$175,000.

The estimated total annual costs for the project and their distribution between the cities are as follows:

Annual debt service (30 years at 4.5%)	\$220,000
Annual net operation and maintenance costs	<u>175,000</u>
Total	\$395,000
<i>Distribution</i>	
City of Gloversville (55%)	\$217,250
City of Johnstown (45%)	<u>177,750</u>
Total	\$395,000

The agreement between the cities of Gloversville and Johnstown calls for a 55/45% split of capital costs and of operation and maintenance for 3 years. The division of operation and maintenance charges will be reviewed every 3 years to reflect the results of samples collected and analyzed.

The final method of allocating costs to the users has not been fully established. The two cities would like to keep the rates in the cities the same, based on the volume of water used, probably with surcharges for industrial users. It is the aim of the Sewer Board and the cities to avoid a rate structure dependent on repeated and critical sampling of industrial users. The average homeowner in the cities will pay for the service based on his or her water usage, and present estimates put the average annual cost at less than \$20 per year per home.

### Application of Plan in Practice

There are many lessons that this case history serves to teach us. Several of the theoretical solutions to this problem had to be abandoned because of the social, economic, and governmental situation. Table 10.26 describes five such inconsistencies, along with the reasons for deviating from theory.

TABLE 10.26  
Inconsistencies between Theory of Design and Actual Practice in Design

<i>Situation</i>	<i>Theoretical Solution</i>	<i>Actual Practice</i>	<i>Reason for Violating Theoretical Solution</i>
Flow BOD	Measured as 5–7 mgd Measured as 20,000– 25,000 lb/day	Designed for 9.5 mgd Designed for 35,019 lb/day	Addition of a large glue-manufacturing plant and another tannery; consideration of future loads
Sludge handling	Digestion plus lagooning was least costly and proved acceptable in the laboratory	Zimpro plus vacuum filtration plus landfill	Lack of state approval because of health hazards of lagooning digested sludge; lack of confidence in efficiency of sludge digestion
Charging for services	Incentive plan based on unit costs for a pound of BOD and suspended solids and a gallon of waste	Percentage of water bill	Ease of charging; elimination of need to sample, police, and analyze industrial wastes; strong representation on joint Sewer Board of tannery industry
Equalization	Theory would indicate that it is needed because of great fluctuations in instantaneous flow and character	In practice, not required because the great number of tanneries and length of travel in sewers provide equalization	Great number of tanneries; increase in cost of construction and operation of equalization basin
Biological treatment	Theory and laboratory results indicate that activated sludge is an excellent method of reducing high BOD	Practice shows it more suitable to use a combination of roughing filters and activated-sludge treatment in series	Activated sludge computed to be about twice the cost <sup>a</sup>

<sup>a</sup>Costs are compared as follows:

	<i>Roughing filter</i>	<i>Activated sludge</i>
Fixed charge	\$0.55/lb	\$0.39/lb
Operating costs	\$0.03/lb	\$0.72/lb
Total costs	\$0.58/lb	\$1.11/lb

It has been reported that the plant experienced grease problems because of ineffective pretreatment by some tanneries (1974/1975). However, more than 90% BOD reduction and about 85% suspended-solids reduction were attained.

This case study serves as an example of a twentieth-century application of joint treatment of raw industrial wastes with domestic sewage.

## **Review Questions**

1. What specific alternatives are open to a municipal official concerning acceptance of industrial wastes? What are the alternatives open to an industrial plant manager when considering joint treatment?
2. List and discuss the 12 advantages of joint treatment.
3. Can all industrial wastes be treated in municipal sewage-treatment plants? What are the limiting concentrations of contaminants, the reason for limitation, and the acceptable pretreatment required for excessive contaminants of each type?
4. What are some of the problems of combined treatment?
5. What can municipalities do to assist industries in waste-treatment practices?
6. What methods are used by municipalities for defraying costs of sewer services and sewage-treatment costs?
7. What method of charging an industry is advocated by both the American Society of Civil Engineers and the American Bar Association? What are its main advantages?
8. In the case history of joint treatment presented in this chapter, what are the pertinent background factors related to its solution?
9. Describe how the stream survey, composite waste sampling and analysis, and laboratory pilot studies were vital to the joint treatment decision.
10. Why was a literature survey necessary?
11. What were the overall planning conclusions?
12. What are some of the inconsistencies between theory and design used in this case study?
13. Does joint treatment of raw wastes represent a reasonable or optimum solution to the problem?

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