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Rest-Area Wastewater Treatment

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To develop guidelines for rest-area wastewater-treatment systems that are capable of complying with the requirements of Public Law 92-500, the principal treatment situations encountered at rest areas have been identified. The quantity and quality of wastewater produced at rest areas were examined through a literature survey and through visits to various state highway departments. The common categories of wastewater-treatment systems in use at rest areas are discussed, and their capability for compliance with the requirements of Public Law 92-500 was investigated. An extended-aeration, activated-sludge plant was shown to be capable of meeting these requirements. Initial results of the study indicated that lack of adequate design criteria results in major problems in planning, designing, and operating rest-area wastewater-treatment facilities. To meet this deficiency, new design criteria and operation guidelines were developed to assist the state highway departments responsible for providing and maintaining wastewater-treatment facilities at rest areas.

The advent of the Interstate highway system has resulted in an increase in travel by a more mobile American public. To accommodate these travelers, the Federal Highway Administration (FHWA) and the state highway departments provide roadside rest areas on the highways.

One of the main problems in the construction of rest areas is that of providing adequate facilities for the treatment and disposal of wastewater. The wastewaters produced at rest areas are characterized by large variations in flow and composition, and the use of sophisticated treatment systems to accommodate these variations requires frequent attention from skilled operators, who are scarce.

The Federal Water-Pollution Control Act amendments of 1972 [Public Law 92-500 (Pub.L. 92-500)] and an increased public concern for environmental quality have prompted FHWA to initiate a program designed to minimize the environmental impact of the highway system. One of the purposes of this program is to develop a treatment technology for rest-area wastewater that will comply with the 1977 requirements of the 1972 amendments. This FHWA-funded research is designed to assist the state highway departments by providing information and guidelines for the design and upgrading of rest-area treatment and disposal facilities.

One segment of the FHWA research was a two-phase study by the Environmental Effects Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) at Vicksburg, Mississippi. The first phase emphasized the survey and assessment of the operating characteristics of existing rest-area treatment systems. The second phase emphasized the development of specific design and operating guidelines.

The phase 1 research collected information about the conditions of existing rest-area facilities. The types and sizes of existing wastewater-treatment systems and their operational characteristics and design parameters were inventoried. The applicable literature was reviewed, and field visits were made to 21 states.

The phase 2 effort consisted of the identification of wastewater-treatment systems that comply with the 1977 requirements of Pub.L. 92-500; the investigation of an extended-aeration, activated-sludge treatment plant with emphasis on its ability to meet the 1977 requirements of Pub.L. 92-500; and the preparation of design guidelines, criteria, and recommendations for selecting wastewater-treatment systems for rest areas.

LITERATURE REVIEW

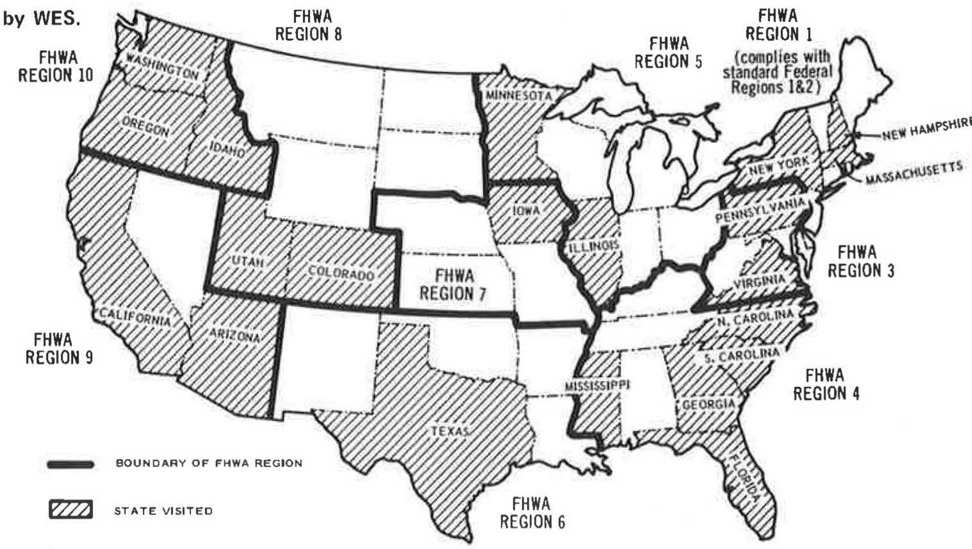
Before a wastewater treatment system is designed, the flow and concentrations of the various constituents of the wastewater must be determined or estimated. Because of the absence of more definitive information, most of the existing rest areas were designed by using the concentrations of an average domestic wastewater. However, since 1971, there have been four important studies of rest-area wastewater and the treatment facilities for it.

Washington Rest Areas

Sylvester and Seabloom (1) studied the wastewater characteristics at four rest areas in Washington. In comparing the characteristics of the rest-area wastewater with those of domestic wastes, they concluded that rest-area wastewater

1. Has essentially no grease or scum materials,
2. Is high in nitrogen, which indicates a preponderance of urine,
3. Has suspended solids (SS) and a 5-day biochemical oxygen demand (BOD_5) that are between those of weak and average domestic wastewaters,
4. Has a chemical oxygen demand (COD) equal to that of a strong wastewater (because of the paper content),

Figure 1. States visited by WES.



5. Has a phosphate content that corresponds to that of weak wastewater, and
6. Has a settleable solids content that is much greater than that of domestic wastewater (because of the high paper content).

Sylvester and Seabloom also found that the amount of wastewater produced per user varied from site to site and that there was a large fluctuation in the flow rate from hour to hour and from day to day. An assumed flow of 13.2 L (3.5 gal)/person/day and an associated BOD_5 of 165 mg/L were used as the basis for sizing different types of wastewater-treatment systems in Washington.

Indiana Rest Areas

In a similar study, Etzel and others (2) studied seven rest areas in Indiana and, from an analysis of their influents and effluents, concluded that "the plants are for the most part substantially underloaded (hydraulically) and accordingly BOD loadings are low." They propose a design flow of 18.9 L (5.0 gal)/person/day and a BOD_5 loading of 3.2 to 4.5 g (0.007 to 0.01 lb)/person. They also recommend that comprehensive traffic data be collected before a rest-area facility is designed.

Illinois and Iowa Rest Areas

Pfeffer (3) studied the characteristics of rest-area wastewater in Illinois and Iowa and, in comparing the results of his study to those of the previous two, concluded that

> the range of average BOD_5 for the various rest areas is from 110 to 204 mg/L (average 150 mg/L). The suspended solids range from 56 to 230 mg/L with an average of 149 mg/L. These data suggested that rest-area wastewater is comparable with normal municipal waste.

Pfeffer also conducted a mail survey to identify design assumptions in various states. He recommends that 12 percent of the highway traffic (assuming an occupancy of 3.1 persons/vehicle) and a wastewater production of 18.9 L (5 gal)/person/day be used as design values for rest-area treatment facilities.

Other States

Zaltzman and others (4) have conducted an extensive study of rest areas. Various rest-area parameters were monitored in Florida, Tennessee, New Hampshire, Colorado, and Iowa. The most difficult parameters to predict, according to them, were accurate forecasts of the average daily traffic (ADT) and the percentage of the ADT that stops at the rest area. After the traffic approaching and that entering the rest areas were monitored, regression models were developed to predict the ADT entering the surveyed rest areas.

Zaltzman and others also sampled rest-area wastewater and concluded that it corresponded to a weak to medium-strength domestic wastewater with respect to BOD_5, COD, total oxygen concentration, SS, and pH. Nitrogen and phosphorus concentrations often exceeded those of strong domestic wastewater.

SURVEY OF REST AREAS

To obtain information about site-selection criteria, the facilities provided, and their flow characteristics and wastewater-treatment systems, WES visited state highway departments in the nine FHWA regions (Figure 1). The survey emphasized areas with well-developed comfort facilities that included flush toilets and, since 60 percent of the rest areas along Interstate highways provide these, it was concentrated there.

Each visit included an on-site survey of at least one rest area and a meeting with the FHWA and state-highway personnel responsible for rest-area construction and maintenance. In some cases, members of the state health agencies or pollution control agencies or both were also present.

Size of Rest Area

As the literature survey had shown, the size of the rest area is usually based on the ADT. Once the ADT at a location is determined, the number of vehicles that will stop at a rest area there is calculated as a percentage of this value. The number of occupants per vehicle is also calculated.

Most rest areas are sized to accommodate expected use for their design life, which is usually taken as 20 years. New York uses a design life of 15 years, and in California, some rest-area buildings are designed to reach capacity in 10 years, although the treatment facilities are designed for 20-year periods.

Rest-Area Components

In the past, rest areas consisted of parking spaces and restrooms. Today, however, they commonly have restrooms with flush toilets and sinks and various electrical equipment. Some rest areas have information centers, pet-walk areas, and scenic walks. In 11 of the 21 states surveyed, trailer dumping stations were provided. The waste from these dumping stations enters into the rest-area treatment facility or into a holding tank.

Most rest areas are landscaped with trees, grasses, and shrubbery. The incorporation of these can improve the functioning of evapotranspiration beds, screen treatment plants from the rest-area user, and shield the rest area from the highway. In Florida and in the midwestern and western states, these plants are sometimes spray irrigated with the waste effluent to supplement the rainfall.

Types of Treatment Systems

The WES field survey found that the criteria commonly used to select a treatment system are

1. Simplicity of operation and maintenance,
2. Freedom from odor, noise, and insects,
3. Capability to accommodate the widely fluctuating hydraulic and organic loadings that are caused by traffic and seasonal changes,
4. Treatment efficiency, and
5. Reasonable initial and operating costs.

One of the main objects of the field survey was to determine the types of treatment systems in use for rest-area wastewater and their distribution. Correlation of the type of wastewater-treatment system to various parameters, such as climate, soil type, or precipitation, was attempted, but the only relation found was the predominant use of evaporative lagoons in regions of low precipitation and high evaporation.

The principal types of rest-area treatment systems found by the survey were (a) septic tanks followed by leach fields, (b) facultative, aerobic, or totally evaporative lagoons, and (c) extended-aeration (EA), activated-sludge package plants.

Although discharge to a municipality is not a common disposal method, it is the most desirable. This method (a) relieves the state highway department of the responsibility of constructing on-site treatment and disposal systems, (b) reduces operation and maintenance (O&M) costs, and (c) fulfills the state's obligation to provide wastewater treatment and remove the wastewaters from the rest areas. However, since most rest areas are not near municipalities, on-site treatment facilities must usually be supplied.

Comparison of the design capacity and actual flows of wastewater-treatment systems at existing rest areas shows that the majority have been hydraulically overdesigned. In most cases, treatment capacities less than 57 000 L/d (15 000 gal/d) would have been adequate.

PROBLEMS ASSOCIATED WITH REST-AREA DESIGN

Inadequate Water Supply

One problem faced by the rest-area designer is that of an inadequate supply of water. At remotely located rest areas, water is often not available. At some facilities, water may be available but not potable, because of contaminants or high salt contents. Treatment to produce potable water is often not feasible, and the water supplies at these areas can be used only for flushing, lawn irrigation, or cleaning. If drinking water is to be available, it must be trucked in. At some locations where adequate water is not available, low-flush toilets have been used.

Lack of Adequate Design Criteria

Another problem in rest-area planning is the lack of adequate design criteria. The BOD loadings used in design calculations range from 2.7 to 9.1 g (0.006 to 0.02 lb)/person/d, and the hydraulic loadings range from 10.2 to 22.7 L (2.7 to 6.0 gal)/person/d. Because the characteristics of rest-area wastewaters are not always known, most states have based design criteria on the characteristics of domestic waste. There is also a lack of data about the variability of wastewater flows. Rest-area use depends on the number of vehicles that stop at the facility, and since traffic flows vary both hourly and seasonally, variations in wastewater-flow patterns may result in the failure of treatment facilities designed by inadequate criteria.

REQUIREMENTS OF PUBLIC LAW 92-500

Certain requirements of Public Law 92-500 are significant in the design and operation of wastewater treatment facilities for rest areas. Section 301(b) of that law requires compliance with effluent limitations that reflect the use of secondary treatment for wastewater discharges from publicly owned treatment facilities by July 1, 1977. Compliance with the limitations necessary to meet water-quality standards for the receiving water is also required by that date.

The Environmental Protection Agency (EPA) requirements for secondary treatment established a minimum national standard. The parameters BOD_5, SS, and pH of the wastewater discharge are specifically limited. Also, some states have promulgated state effluent limitations for BOD_5 and suspended solids that are more stringent than secondary treatment levels and have established limits for the nutrients, phosphorus and nitrogen.

Compliance with water-quality criteria (stream standards) may require achieving a higher degree of treatment than secondary. Water-quality criteria vary from state to state because of differences in climate, geography, and the major uses of the water. All state standards include an antidegradation statement and limits for dissolved oxygen (DO), pH, coliform bacteria, and nitrate nitrogen in streams used as public water supplies. The antidegradation statement may prohibit any additional discharge of pollutants to a water of high quality. Some states also limit ammonia nitrogen and phosphorus. The amount of pollutant permitted for discharge to a stream will depend on the flow and concentration of the effluent in relation to the flow and assimilative capacity of the stream. Discharge into a stream with an extremely low flow may require such a high degree of treatment that a no-discharge treatment facility becomes necessary. Therefore, the selection of a site for a rest area should include an evaluation of the location, classification, and assimilative capacity of the receiving stream.

The National Pollutant Discharge Elimination System (NPDES) permit program established by Public Law 92-500 requires that the EPA regional administrator issue a permit before the discharge of effluents containing pollutants. Operators of rest areas are required to obtain a permit for wastewater discharge.

The issuance of permits by states is not included as part of this program, but the procedures followed and the terms and conditions of the permits issued will be similar in most states. The state-program elements necessary for participation in the NPDES were published in the Federal Register on December 22, 1972.

One important factor in this system is the participation of the public by notices, hearings, and appeals. When an application for an NPDES permit is made, a draft permit based on the information contained in the application or obtained from a site inspection or both is developed. The public is notified of the intention to issue a permit, and interested persons can obtain copies of the application, draft permit, or other pertinent information. After a 30-d response period, the decision regarding the permit is made, and whether the permit is issued or not, both sides may request an additional hearing.

The section of the NPDES that specifies effluent limitations is the most pertinent to the permittee. For wastewater-treatment facilities, the 1977 limits for BOD, SS, fecal coliform bacteria, and pH are given below.

Parameter	Limit 30-Day Mean	7-Day Mean
BOD_5 (arithmetic mean)		
Influent > 200 mg/L, mg/L	30	45
Influent < 200 mg/L, mg/L	15% of influent	45
SS (arithmetic mean)		
Influent > 200 mg/L, mg/L	30	45
Influent < 200 mg/L, mg/L	15% of influent	45
Fecal coliform bacteria (geometric mean), count/100 mL	200	400
pH of effluent	>6.0, < 9.0	>6.0, < 9.0

Proposed rules in the Federal Register of August 15, 1975, eliminate the fecal coliform requirement for secondary treatment and exclude systems that treat only domestic waste and do not use chemical addition as a part of the treatment process from the pH requirement. In addition to the concentration limitations, the permits specify weekly and monthly quantitative limits by weight for BOD and SS. If it is necessary to maintain water-quality standards, other parameters such as ammonia nitrogen, phosphorus, and minimum DO may also be regulated by the permit.

If the final effluent limitations for an existing discharge cannot be achieved immediately, a schedule of compliance may be included to allow reasonable time for modification.

Figure 2. Methods for determining wastewater flows.

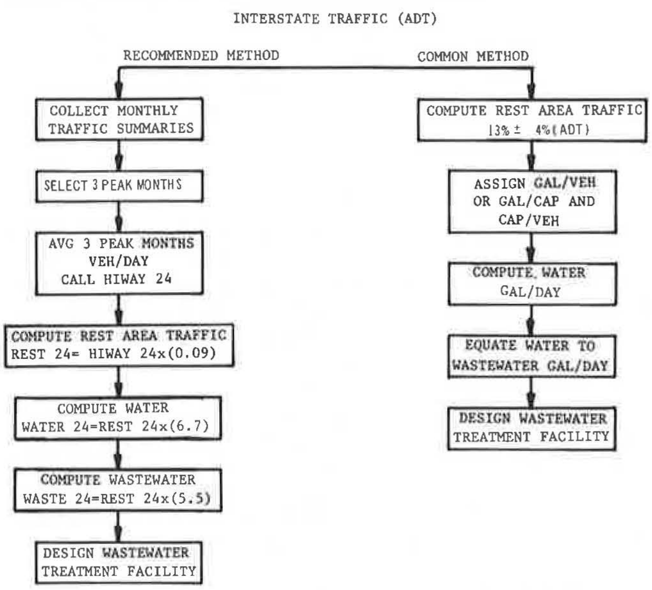


Table 1. Wastewater strengths at various rest areas.

State	BOD (mg/L)	COD (mg/L)	SS (mg/L)	pH
Colorado[a]				
High	156	507	504	8.3
Low	23	145	72	7.8
Mean	78	203	208	8.0
S.D.[b]	45	103	118	0.14
Florida[a]				
High	300	440	530	8.6
Low	140	216	28	6.8
Mean	181	342	186	7.4
S.D.[b]	43	60	111	0.55
Iowa[a]				
High	561	787	652	8.5
Low	59	140	38	7.1
Mean	210	383	224	7.9
S.D.[b]	137	209	153	0.35
New Hampshire[a]				
High	330	480	684	8.4
Low	90	197	1	6.4
Mean	203	330	208	7.2
S.D.[b]	62	82	165	0.65
Tennessee[a]				
High	223	883	310	8.7
Low	63	160	16	7.1
Mean	158	362	124	7.7
S.D.[b]	52	174	72	0.45
Mississippi[c]				
High	432	–	839	–
Low	12	–	4	–
Mean	124	–	140	–
S.D.[b]	86	–	145	–

[a]Data collected by Zaltzman and others (4).
[b]S.D. = standard deviation.
[c]Data collected by WES.

WATER USE, WASTEWATER PRODUCTION, AND WASTEWATER CHARACTERISTICS

Most of the rest areas designed to date have assumed a usage that is a percentage of the ADT. Water supply and wastewater-treatment facilities are then designed on the basis of an assigned occupancy per vehicle and a water use per occupant. These values are usually taken as 3.1 persons/vehicle and 18.9 L (5 gal)/person.

Zaltzman and others (4) have developed a method for predicting rest-area traffic, water use, and wastewater production. The contrast between this method and the method currently used by state highway departments for determining sizes of rest-area water supplies and wastewater-treatment facilities is shown in Figure 2. In the new method, monthly traffic summaries are collected for a 1-year period. The three peak months are selected from these summaries, and their average number of vehicles per day is calculated (HIWAY 24). HIWAY 24 is then used in the same way that the ADT is used at present. The number of vehicles per day stopping at a rest area (REST 24) is assumed to be 9 percent of HIWAY 24. Water use and wastewater production per vehicle vary from site to site; some typical values are given below (1 L = 0.26 gal).

State	Water Use (L/vehicle) Peak	Avg	Min	Wastewater Production (L/vehicle) Peak	Avg	Min
Florida	20.8	17.0	15.1	18.9	16.1	13.2
Tennessee	26.5	18.9	8.5	26.5	18.9	8.5
New Hampshire	26.5	24.6	20.8	22.7	21.8	16.1
Colorado	20.8	16.1	8.5	18.9	16.1	11.4
Iowa	20.8	16.1	8.5	20.8	16.1	8.5

Values given in these tables may be used as design guidelines. The concentrations of the constituents of the wastewater also affect the size of a wastewater-treatment system. Previously, rest-area wastewater was assumed to have characteristics similar to those of a medium-strength domestic wastewater (BOD_5 = 200 mg/L and SS = 200 mg/L). However, the data collected by Zaltzman and others and by WES (Table 1) indicate that BOD_5 and SS are in the range 125 to 200 mg/L, which corresponds to a weak domestic wastewater. Therefore, the values listed in Table 1 may be used as design guidelines.

COMMON REST-AREA TREATMENT METHODS

The following treatment methods are currently used at rest areas: septic tanks and leach fields or sand filters, oxidation ponds, and EA, activated-sludge package plants.

Septic Tanks

In a septic tank system, the wastewater enters directly into the tank, where it is retained (normally for 24 h). During this time, some of the solids settle to the tank bottom where anaerobic decomposition slightly reduces their volume. The remainder of the wastewater (including its SS, bacteria, soluble organics, and nutrients) becomes effluent and flows into the leach fields or sand filters.

Septic tanks are usually inexpensive, are easy to install and maintain, and can handle small variations in flow and periods of nonuse. However, high groundwater, high precipitation, and poor soil conditions may inhibit the effectiveness of the leach fields. Also, the soil in the leach fields may become clogged and the system may be hydraulically overtaxed, which will result in the surfacing of partially treated wastewater. In some areas, land requirements may prohibit the use of leach fields.

Oxidation Ponds (Lagoons)

In oxidation ponds, facultative bacteria metabolize the organic matter in the raw waste for energy and growth and produce carbon dioxide and water. Algae, on the other hand, use carbon dioxide, sunlight, and inorganic materials to produce algae protoplasm and oxygen, which are used by the bacteria to complete the cycle. The solids settle to the bottom for anaerobic decomposition.

Oxidation ponds are less susceptible to organic or hydraulic shock loading than are other treatment methods, their O&M costs are low, and they require little, if any, electrical or mechanical equipment. However, they usually achieve only a low degree of treatment and, in the summer, their effluents may be algae-laden. They may also present problems of odors and the pollution of groundwater. The use of oxidation ponds as the only means of treatment is limited because a high degree of treatment is generally required for rest-area wastewater effluents.

EA, Activated-Sludge Package Plants

Extended aeration is a modification of the conventional activated-sludge process and involves an aeration tank in which the incoming raw waste contacts a heterogeneous culture of microorganisms in the presence of oxygen. The bacteria use the organic matter as a source of food and energy, and the wastewater then flows into a clarifier where the biological culture is removed and returned to the aeration tank. These package plants can be installed on narrow rights-of-way or in areas of high precipitation. Additional units can be added if the volumes of wastewater increase. However, the use of EA systems is handicapped by high capital investment and O&M costs, as well as by the need for trained operators.

Land Treatment

Land treatment of liquid waste is divided into three variations: rapid infiltration, spray irrigation, and overland flow. Rapid infiltration is the application of a considerable depth of wastewater to a highly permeable soil for the generation or replenishment of the groundwater. Spray irrigation is the application of wastewater to vegetated land. Overland flow is the application of wastewater to an impermeable soil where the wastewater flows over a sloping terrain and is collected in a ditch or natural stream.

At rest areas, spray irrigation has been used as a tertiary treatment for effluents from EA, activated-sludge plants and oxidation ponds. This offers an advanced degree of treatment, low design and O&M costs, and removal of the discharge to surface areas. However, it may require land areas that can be isolated from the public.

Evaporative Lagoons (Ponds)

Evaporative lagoons are usually arranged in series. Raw wastewater flows into the first pond where much of the solid matter settles to the bottom and undergoes anaerobic decomposition; the remainder of the wastewater undergoes aerobic treatment. The partially treated wastewater then flows into a second pond where it evaporates or is used for spray irrigation.

These ponds eliminate discharge of the effluent, are inexpensive to operate and maintain, and can withstand large fluctuations in flow and shock loadings. The method is limited to areas where evaporation exceeds precipitation plus the volume of wastewater. Odor and nuisance (e.g., mosquito) problems must also be considered.

APPLICABILITY OF WASTEWATER-TREATMENT SYSTEMS TO USE AT REST AREAS

Because of the 1977 requirements of Public Law 92-500, rest-area wastewater-treatment systems must produce an effluent that meets the standards for secondary treatment. This applies to both existing and planned systems.

Evaporative lagoons and land-treatment systems (with the exception of overland flow) have no point-source discharge and therefore should meet the requirements of Public Law 92-500. However, in the design of these systems, the groundwater supplies must be protected against possible contamination by the wastewater.

Properly designed septic-tank-and-soil-absorption systems have also no discharge and should meet the requirements of Public Law 92-500. However, sound construction procedures must be followed to ensure correct operation of these systems and to protect groundwater supplies from possible contamination.

Facultative lagoons may not produce an effluent that meets the 1977 requirements of Public Law 92-500 because of the presence of algae. Algae not only contribute to a high suspended-solids concentration in the effluent, but also have an associated BOD_5 that often exceeds the effluent requirement. However, additional treatment of lagoon effluents to remove the algae may improve their quality enough to meet the requirements of Public Law 92-500. This additional treatment could be by slow sand filters, rock filters, and upflow sand filters. (However, recent EPA-proposed rule changes may alleviate the effluent suspended-solids requirements for lagoons.)

EA, activated-sludge package plants in use at schools, subdivisions, and apartment complexes have been shown to be capable of producing an effluent that meets the requirements of Public Law 92-500. However, EA plants in use at rest areas have not been shown to do so. Therefore, WES monitored an EA plant in use at a rest area to determine its compliance or noncompliance.

The EA plant monitored in this study was located at the Toomsuba Rest Area on the westbound lane of I-20, 19 km (12 miles) east of Meridian, Mississippi. This rest area is equipped with an information center, a parking area, picnic tables, drinking fountains, a trailer dumping station, and wastewater-treatment facilities.

The wastewater-treatment facilities consist of a comminutor; three aeration tanks, each having a capacity of 18 900 L (5000 gal), operated in series; a settling tank having a capacity of 9450 L (2500 gal); a sludge holding tank having a capacity of 4725 L (1125 gal) with recycle to the first aeration tank; a chlorine-contact chamber having a capacity of 1420 L (375 gal); and a postaeration chamber (Figure 3). The plant receives wastewater

Figure 3. Plant layout and sampling points.

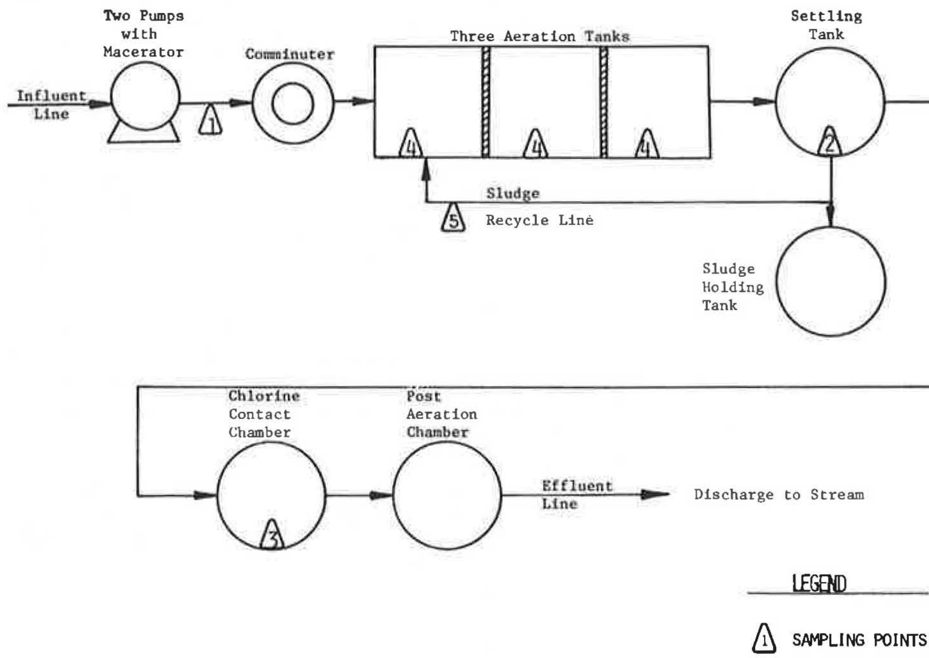


Figure 4. Influent and effluent 5-day biochemical oxygen demand.

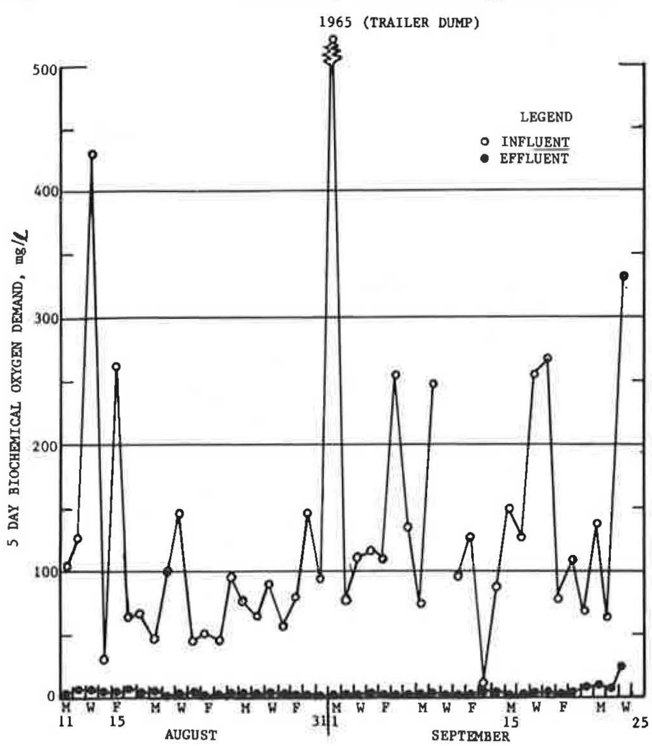
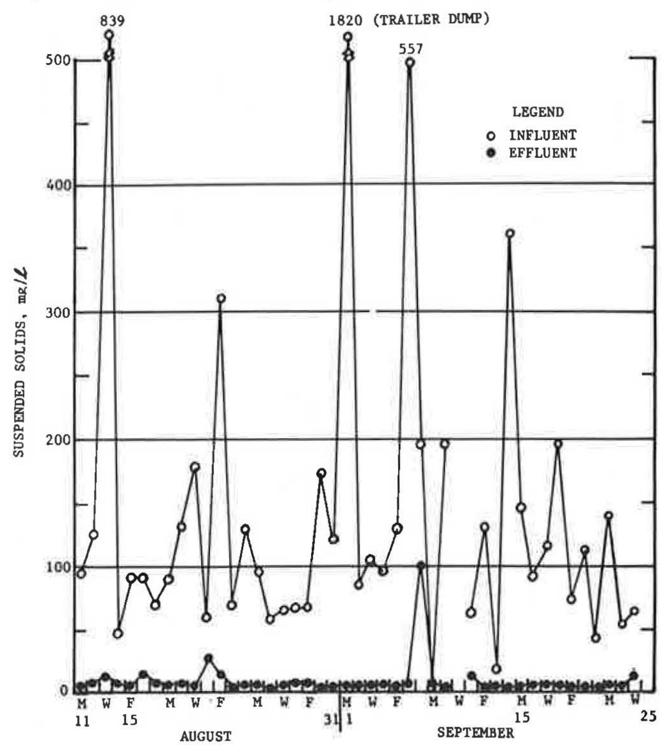


Figure 5. Influent and effluent suspended solids.



from a forced main serviced by two submersible, centrifugal pumps with macerators and discharges its effluent via a ditch to a nearby stream. It is currently operating under a permit from the Mississippi Air and Water Pollution Control Commission that was issued October 15, 1974.

Sampling points are located at the influent line just prior to the comminutor (1), the settling tank (2), the chlorine-contact tank (3), each aeration tank (4), and the sludge-return line (5) (Figure 3).

Random-grab samples of the influents and the final effluents were collected daily over a 45-d period between 8:00 a.m. and 6:30 p.m. Composite samples of the influent were also collected to establish the relation between the grab and composite samples.

The flow was measured with automatic flow recorders in the chlorine-contact chamber. Water use was measured with a 3.8-cm (1.5-in) water meter equipped with an impulse switch connected to an event recorder located on the water line to the hospitality house.

The analysis of the wastewater samples included ammonia; nitrate; phosphate; pH; total, settleable, suspended, dissolved, and volatile suspended solids; BOD_5; and fecal coliform bacteria. All analyses were carried out by procedures given in Standard Methods (5). Figures 4 and 5 illustrate influent and effluent data for BOD_5 and SS. Examination of the data shows that

1. All effluent BOD_5 grab and composite samples met the requirements of Public Law 92-500,
2. All 7-d mean BOD_5 met the requirements of Public Law 92-500,
3. All 30-d mean BOD_5 met the requirements of Public Law 92-500,
4. One SS grab was in excess of the Public Law 92-500 requirement,
5. All 7-d mean SS met the requirements of Public Law 92-500,
6. All 30-d mean SS met the requirements of Public Law 92-500,
7. All pH samples met the requirements of Public Law 92-500,
8. One 7-d mean fecal coliform bacteria failed to meet the requirements of Public Law 92-500 (this was attributed to malfunction of the chlorination unit), and
9. The overall plant efficiency (based on the average of the grab samples) was 97.5 percent removal of BOD_5 and 92.3 percent removal of SS.

Thus, the results of this study showed that a well-operated EA plant (when used at a rest area) can meet the 1977 requirements of Public Law 92-500.

CONCLUSIONS

1. Water use rates, wastewater-production rates, and wastewater characteristics, as related to the design of treatment facilities and to existing rest-area facilities, are extremely site specific. The design criteria currently in use by various states show a range of hydraulic-loading rates from 10.2 to 22.7 L (2.7 to 6.0 gal)/person/d and an organic (BOD_5) loading from 2.7 to 9.1 g (0.006 to 0.02 lb)/person/d.
2. Rest-area wastewater should not present any overall treatment problems from the standpoint of its composition, even in view of the following characteristics: The COD to BOD ratio is generally higher for wastewater from rest areas than for domestic wastewater, because of the presence of a larger fraction of nonbiodegradable organics. The ammonia nitrogen concentration of rest-area wastewater is higher than that of domestic wastewater because of its higher urine content. The variation in individual wastewater parameters is substantially greater for rest areas than for domestic sources, which creates greater difficulty in generating meaningful design criteria. Adequate nutrient (particularly nitrogen) and COD removals are sometimes difficult with secondary treatment systems, and tertiary treatment may be required at some rest areas.
3. The lack of adequate design criteria has created major problems in planning, designing, and operating rest-area wastewater-treatment facilities. In particular, the hydraulic and organic loading criteria assumed have led to the overdesign of most facilities.
4. The work of Zaltzman and others (4) and others has shown that a more accurate estimate of hydraulic loading rates is in the range of 16.1 to 21.8 L (4.25 to 5.75 gal)/vehicle/d, depending on geographical location and site-specific conditions, and assuming an average waste strength of 125 to 200 mg/L for BOD_5, and 125 to 200 mg/L for SS.
5. The commonest categories of wastewater-treatment systems in terms of use are biological and no-discharge systems. These systems include septic tanks followed by leach fields or sand filters; facultative, aerobic, or totally evaporative ponds; and EA, activated-sludge plants.
6. Wastewater-treatment systems that have been used at rest areas and that are capable of complying with the effluent limitations of Public Law 92-500 include septic tanks followed by leach fields or evapotranspiration beds, EA package plants, facultative lagoons followed by filtration or land treatment, and totally evaporative lagoons.
7. There is no single, best solution to the rest-area wastewater-treatment problem that can be applied on a national, regional, or even state-by-state basis. The design of each wastewater-treatment facility must be site specific.

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