# Recreational Vehicle Waste Disposal Stations at Highway Rest Areas

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16. Abstract

A study of recreational vehicle waste disposal at highway rest areas was conducted from 1980-1982. RV wastewater is significantly stronger than restroom wastewater in BOD, COD, and suspended solids. It also contains preservative compounds, most of which contain formaldehyde or a formaldehyde derivative. With adequate dilution, these wastes should not interfere with waste treatment by mixed cultures of aerobic or anaerobic bacteria or algae. There is potential that waste treatment facilities will be affected by improper use of the disposal stations, such as for disposal of hazardous wastes. In addition, improper use may lead to temporary unsanitary conditions around the station.

Equations to estimate disposal station use and loading factors, and design equations for treatment of RV wastes are presented.

The public perceives the stations to be beneficial and cost-effective provided they are paid for by RV owners. RV owners are willing to pay an annual fee which will cover the costs of construction, operation and maintenance of the stations.

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# RECREATIONAL VEHICLE WASTE DISPOSAL STATIONS AT HIGHWAY REST AREAS

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# SUMMARY

A study of recreational vehicle wastewater disposal at highway rest areas was conducted from 1980 through 1982 to evaluate the feasibility, costs, and benefits of disposal stations constructed at highway rest areas in Washington. The study addressed the quantity and composition of the wastewater, the effects of preservative compounds used in wastewater holding tanks, the performance and design of various treatment systems handling RV wastes, and the costs and benefits of the program.

A review of previous studies combined with a survey of RV owners and RV accessory stores revealed a change in use of preservative or deodorizing chemical. Toxic, persistent chemicals such as zinc or chlorophenols are no longer commercially available. At present formaldehyde is the predominantly used active ingredient, with enzymes, detergents, perfumes and dyes often also incorporated into the product.

## RV Wastewater Quantity and Quality

RV holding tanks were sampled in summer, 1981. Composited samples were analyzed for total and volatile suspendid solids (SS), total and soluble chemical oxygen demand (COD), and five-day biochemical oxygen demand (BOD). Individual holding tank contents were highly variable. However, mean values were determined with 95% confidence intervals of less than 20% of the mean. The average composition is total SS 3120±490 mg/L, volatile SS 2460±410 mg/L, total COD 8230±1430 mg/L, soluble COD 2930±560 mg/L, and five day BOD 3110±530 mg/L. Waste volume, including rinse water, is 62±10 L. Concentrations of formaldehyde measured in tanks where a formaldehyde additive had been used averaged 250±60 mg/L, whereas the concentration averaged over all tank contents was 170±60 mg/L. Since the formaldehyde dosage for most of the additives is usually about 1000 mg/L, considerable formaldehyde loss occurs in the holding tank.

## Frequency of Disposal Station Use

Traffic counting was performed in 1981 and 1982 to determine frequencies of disposal station use at existing stations and to develop means to predict average and peak use at possible new stations. A maximum use rate of approximately 11 vehicles per hour represents the capacity based on moving vehicles into and out of the disposal station and completing the necessary hookup, draining and rinsing operations. Use rates this high involve queuing and were observed only at the most heavily used stations and only for a few hours at a time on weekends and holidays. The highest daily use rates observed were 230 vehicles at SeaTac rest area (two disposal stations) on Memorial Day and Independence Day. These values are used in determining peak use rates.

Average use rates can be related to highway traffic passing a rest area or to vehicles stopping at a rest area. The factors varied considerably for rest areas along I-5, which are influenced by commuting traffic, and the other rest areas, most of which are in eastern Washington. Factors appropriate for the maximum usage months of July and August are 0.05 and 0.10 vehicles entering the rest area per vehicle passing on the highway for the I-5 corridor near Seattle or Vancouver and for the eastern Washington sites, respectively. Disposal station use is 0.03 and 0.06 vehicles using the disposal station per vehicle entering the rest area for the two types of rest area sites, respectively. Hence, average disposal station use for the maximum months can be estimated by multiplying the average daily traffic values for the July-August period by 0.0015 or 0.006, depending on the rest area location.

Hydraulic and organic loadings can readily be computed using the mean values for holding tank (plus rinse water) contents. Most components of treatment or disposal systems should be designed to handle average loads for the maximum usage months. For parts of the system that must be sized for shorter peak periods, a maximum hourly rate of 11 vehicles per hour may be used or a maximum daily rate may be calculated by multiplying the average rate by 230/80, which is the peaking factor observed at the SeaTac rest area.

Septic tanks must also be sized to accommodate sludge and scum accumulation over periods longer than the July-August peak months. The design loading for the July-August period, when converted into RV's per month, can be multiplied by six to obtain the estimated annual use of disposal stations in Washington.

## Toxicity of Preservative Compounds

The potential toxicity of RV additives to microorganisms important in biological waste treatment was assessed by anaerobic and aerobic bacteria toxicity assays and the *Selenastrum capricornutum* algal toxicity assay. Screening tests with a variety of commercial products and with formaldehyde showed that the toxic response was due to formaldehyde alone, not to dyes or perfumes or to enzymes, detergents or unspecified ingredients.

Formaldehyde is reactive in wastewater solutions and can combine with many components of wastes. Measurements with formaldehyde added to RV waste showed that a 45 to 75% decrease in concentration can occur during normal storage in holding tanks. This decrease is consistent with the observed concentration of 270 mg/L in holding tanks where a formaldehyde additive was used. Hence, the concentration of formaldehyde in waste is much lower than the dosage added to the holding tank.

Anaerobic toxicity was measured by inhibition of methane and carbon dioxide gas production. Noticeable effects (10% decrease in gas) occurred at concentrations of 10 to 40 mg/L; nearly complete inhibition was found at concentrations greater than 100 mg/L.

Aerobic toxicity was assessed by measuring oxygen uptake rate. Formaldehyde was considerably less toxic to the aerobic bacteria, with slight inhibition noted at concentrations greater than 400 mg/L. Bacterial cultures eventually acclimated to and used concentrations up to 800 mg/L.

Growth of *S. capricornutum* was measured to assess relative toxicity to algae. Formaldehyde is much more toxic to this alga than to the bacteria in the other biossays. Concentrations of 1 mg/L caused detectable reduction in growth, while concentrations of 5 mg/L caused nearly complete inhibition. This result may not be as troublesome as it appears, since *S. capricornutum* is not necessarily an important species in treatment lagoons. In fact, bacteria and algae in all the treatment processes will acclimate to formaldehyde or be selected for formaldehyde resistance.

The results do indicate that formaldehyde is toxic at moderately low concentrations, especially to unacclimated microbes. Treatment of RV disposal station wastes without dilution by restroom wastewater is not advantageous. Acclimation and selection for formaldehyde resistance can be expected, but dilution through combined waste treament is preferable to separate RV waste treatment.

## Effects on Treatment Systems

Septic tank and drainfields were sampled from systems serving RV disposal stations to determine the impact of the RV waste on operation of the systems. Septic tank effluents were found to have COD and SS concentrations much higher when treating undiluted RV wastes than when treating domestic wastewater or restroom wastewater. Formaldehyde concentrations, though, were reduced to about 5 to 10 mg/L, values much lower than the dosages or those found in RV holding tanks. Drainfield samples also were found to have high COD and BOD concentrations and similar formaldehyde values.

Septic tank design practices when RV wastes are treated must be modified to account for increased sludge and scum accumulation. Drainfields must be sized to accommodate the increased suspended solids and BOD loadings that will pass through the septic tanks. Septic tank operating data and RV waste loadings are analyzed and design procedures developed so that tanks can be sized for sludge and scum accumulation from RV wastes. It is suggested that tanks be sized for at least one year's accumulation of sludge and scum. Drainfield areas should be increased by approximately a factor of 2 when RV wastes are treated without dilution.

Lagoon systems in Washington are designed to evaporate wastewater, while maintaining organic loadings that are low enough to prevent anaerobic conditions and nuisance odors. Monitoring of a lagoon at the Selah Creek (northbound) rest area revealed no problems in lagoon performance that could be related to RV wastes. The presence of RV wastes could be detected by absorption spectra of the blue dye used in nearly all RV additives. Some leakage from the lagoon was detected by a lithium tracer study, by electrical conductivity measurements and by a comparison of inflow and evaporation.

No changes in design procedures for lagoon system are recommended based on the present study. Lagoons should be sized for complete evaporation and should not have a BOD loading greater than 4.5 g BOD/m$^2$-day (40 lbs BOD/acre-day). Since formaldehyde in RV wastes may be toxic to some algae, it is recommended that the ratio of total wastewater to disposal station wastewater always be greater than five. This dilution, combined with chemical reactions and biodegradation, should maintain sufficiently low concentrations in the lagoons.

Effects on aerobic biological systems were assessed by attempting to measure effects of tank loads of waste disposed at the LaConner, Washington, treatment plant and by mathematically modeling the response of various size plants to RV waste loads. For a very small plant (33,000 gallons per day) and a heavily used RV disposal station, a noticeable inrease in oxygen utilization in the plant and in effluent soluble BOD can be expected. The effects are caused by the increase in BOD loading to the plant. Plants the size of the LaConner plant (100,000 gallons per day) should show no measurable effects, and none in fact could be found at that plant.

RV disposal station wastes are not expected to have adverse impacts on municipal treatment system using aerobic biological treatment.

## Costs and Benefits of Disposal Stations at Rest Areas

In addition to the technical evaluation of the project, an economic evaluation was conducted to determine the overall costs of the disposal station program. In addition, vehicle owners in Washington were surveyed to assess RV owners' and non-owners' perceptions about the program. The annual costs for the ten existing disposal stations, including amortized construction, operation and maintenance with an additional allowance for vandalism damage, are estimated to be between $128,000 and $215,000/yr. Revenues for the program are presently $180,000/yr, based on a $1/vehicle yearly license tab fee for recreational vehicles. The program is marginally self-sustaining, but experience with maintenance and operation is still very limited, and RV owners' fees may have to be increased to properly maintain ten disposal stations.

Approximately 500 vehicle owners responded to a mail survey in 1982. More than half of the responding RV owners were aware of the disposal station program, and more than one-fourth have used the disposal stations at least once. A large majority of all vehicle owners responding thought the program to be worthwhile, predominantly because of the convenience to RV users and because of reduction of illegal dumping and its concommitant health hazards. A significant fraction of the RV owners believed a maximum annual charge greater than the $1/yr now charged would be reasonable. Non RV owners often said the program should be paid for by users.

A variety of non economic costs and benefits were also identified; one merits emphasis. Disposal of large volumes of waste or toxic or hazardous wastes at the disposal stations could do real harm, as well as be extremely costly to clean up. The statutory basis for prosecution for misuse of the disposal stations should be thoroughly researched. WSDOT personnel and the State Patrol should check for illegal disposal station use and aggressively stop any misuse.

# CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations in this section are grouped according to the chapter (in this report) in which they are discussed.

1.1) The literature search revealed a recent study (Pearson et al., 1980a, b) of RV wastewater treatment and two studies of recreational vehicle holding tank wastewater. These studies provided baseline data for our program of sampling and analysis of recreational vehicle wastewater. The studies provided no information concerning frequency of use of disposal stations at highway rest areas.

1.1) Public agencies, including highway departments in the western U.S., state parks and private campgrounds, were surveyed by mail and phone to obtain information on design, operation, and maintenance of disposal stations. A wide variety of experiences was found ranging from abandonment of disposal stations after short periods of unsatisfactory operation to routine operation of stations at little expense or effort from maintenance personnel.

1.3) A wide variety of preservative compounds intended to deodorize, perfume, and/or solubilize holding tank contents are available in Washington State. The majority of the products available and commonly used contain formaldehyde or paraformaldehyde as their active ingredient. Other ingredients often include blue dye and perfume. Other additive products include proprietary buffers and enzyme preparations. RV owners use household cleaning products or no additive a significant fraction of the time.

1.4) In the past, zinc and phenolic compounds were used in preservative products. These have disappeared from the market place and are no longer used in RV holding tanks.

1.5) Formaldehyde is the preservative compound that potentially has the greatest affect on treatment system performance. The literature on formaldehyde chemical reactivity, biodegradation and toxicity is extensive. Formaldehyde will be removed to a significant extent due to chemical reactions with waste constituents. Formaldehyde is toxic to microorganisms that carry out biological waste treatment, as well as to higher organisms from fish to humans. Formaldehyde is also biodegradable by waste treatment microorganisms under proper environmental conditions and with acclimation. The literature pointed to the need to test toxicity and biodegradability of formaldehyde and preservative compounds with waste treatment microbial cultures.

2.1) While the contents of particular holding tanks are extremely variable, the mean volume and concentration have been determined with 95 percent confidence levels of 10 to 20 percent of the mean. Thus, average loadings at well used rest areas can be estimated reasonably accurately based on the number of vehicles using a rest area disposal station.

2.2) The loadings expected are 190 g TSS, 150 g VSS, 510 g COD, 190 g $BOD_5$, and 11 g formaldehyde in 62 liters of wastewater and rinsewater discharged from an RV holding tank.

2.3) Disposal station use varies seasonally. Maximum usage rates are found in July and August and are two to three times greater than rates for April, May or late September. Rates during late autumn, winter, and early spring were not measured but are believed to be very low. Average usage in the peak two months has been selected as the appropriate design basis for waste treatment design.

2.4) Design loadings can be developed by one of two equations:

(July-August Highway ADT) x (Rest Area Use to ADT Ratio)
x (Disposal Station to Rest Area Use Ratio)
= (Disposal Station Use (veh/d))

(July-August Rest Area Use (veh/d)) x (Disposal Station to Rest Area Use Ratio) = (Disposal Station Use (veh/d))

Use rates can then be multiplied by the loadings per use to obtain hydraulic and waste loadings expected from each disposal station.

2.5) July-August disposal station use rates ranged from 80 vehicles per day at Sea-Tac rest area to 25 vehicles per day at Selah Creek NB. These rates (along with ones measured at Gee Creek NB and Schrag WB) constitute three percent and six percent of the rest area users in Western Washington near larger population centers and in relatively remote Eastern Washington sites, respectively . At sites proposed for disposal station development, these factors are appropriate for estimating use.

2.6) Use also may be estimated based on highway traffic. In Eastern Washington, approximately ten percent of the vehicles stopped at each rest area. When combined with six percent frequency of disposal station use, 0.6 percent of the highway traffic are expected to use a rest area disposal station. In Western Washington, especially where commuter traffic is a large fraction of the average daily traffic, there are poor correlations between highway use, rest area use, and disposal station use. In the absence of better information, values obtained at Sea-Tac might be used. 0.15% of the average daily traffic (for weekly periods) used the disposal station. Values computed for individual days were extremely variable.

2.7) Peak use rates of 230 vehicles per day for two disposal station lanes (115 vehicles/disposal station/d) occur after summer holiday weekends at Sea-Tac Rest Area. These rates represent use of the disposal station lanes at their capacity, which is about 11 vehicles per hour, over several hours in the afternoon and evening.

2.8) Peak daily use at other locations can be estimated as three times the average July-August daily use.

2.9) Annual average use rates were not determined in the study. Based on extrapolation of usage to low values during winter months, the annual loading can be estimated as six times the average of the July and August monthly loadings, converted to vehicles per month.

3.1) A number of biological assays testing toxicity of formaldehyde have been reported in the literature. The toxicity varies significantly depending on the species used, the duration of the test, whether the organisms were acclimated to the toxicant prior to testing, and whether the toxicant was fed as a pulse or continuously.

3.2) A mixed culture of anaerobic microorganisms representative of those important in waste treatment has significantly reduced metabolic activity when exposed to between 100 and 150 mg/L formaldehyde. The toxicity is likely to be less severe in situations where the organisms are allowed to acclimate to higher formaldehyde concentrations. Enzyme- and oxalate-based additives are not toxic to anaerobic organisms.

3.3) Aerobic toxicity assays indicated that aerobic micro-organisms can acclimate to formaldehyde or oxalate concentrations higher than expected to be found in RV wastewater. Paraformaldehyde toxicity was longer-lasting than toxicity resulting from other preservatives, probably because paraformaldehyde dissolves slowly. This is not expected to cause a problem in RV wastewater treatment operations.

3.4) Formaldehyde is toxic to a pure culture of a test alga, Selenastrum capricornutum, at low concentrations (3 to 5 mg/L). The lack of any noticeable problem in the algal treatment pond at Selah Creek rest area after the RV disposal station was opened suggests that a mixed culture including several species of bacteria and algae is less senstive to formaldehyde than a pure culture of the test alga. Nevertheless, monitoring of the Selah Creek lagoon should be continued so that any developing problem can be detected at an early stage.

4.1) A septic tank-drainfield treatment system at Wenberg State Park has been operating for several years receiving exclusively RV wastewater. A septic tank-drainfield system receiving RV wastewater at Dash Point State Park failed recently. Formaldehyde concentrations in both these systems and in septic tanks studied by Pearson et al. are less than 10 mg/L, indicating that most of the influent formaldehyde had been removed by physical, chemical, or biochemical reactions. The effluent from septic tanks receiving RV waste is much more concentrated in organics and solids than domestic wastewater.

4.2) There are no well-founded correlations to design septic tanks accounting for solids accumulation, hydraulic detention time, and potential inhibition of biological activity due to toxicants in the wastewater. A model has been developed which can be used to size septic tanks and which accounts for all these factors.

4.3) Procedures for sizing drainfields for concentrated septic tank effluents are not agreed upon. Based on one recent study, we recommend sizing drainfields for RV septic tank effluent at twice the size one computes for a comparable flow rate of domestic septage.

4.4) Evaporative lagoons at highway rest areas with RV disposal stations should receive mixed influent including restroom waste as well as RV waste. Present design procedures are acceptable for sizing such lagoons, as long as the organic loading contributed by the RV waste is included in the calculations.

4.5) The lagoon at Selah Creek is leaking water at a rate that is within the legal guidelines for such facilities. There is no evidence at this time that lagoon water is contaminating the drinking water supply at the rest area.

4.6) The Selah Creek lagoon is operating acceptably after receiving RV wastes for 2 years. There has been a slight increase in blue coloring in the lagoon, due apparently to the dyes in RV additives. This is not thought to be a serious concern.

4.7) After busy holiday weekends lagoons receiving RV wastes may be organically overloaded, but they recover in a few days with no apparent residual effects.

4.8) Small activated sludge treatment plants are not likely to be affected in any significant way by moderate discharges of RV wastewater into the plant. This conclusion was verified by analyzing the performances of such a plant during and after an episode in which RV waste was mixed with the plant influent. The operator indicated that in his experience, such an event had never caused a plant upset.

4.9) The results suggest that holding tank additives presently on the market will not damage properly designed and operated treatment systems. However, surveillance of such systems is recommended to minimize and document any long-term impacts that may occur. Persistent, non-degradable preservatives may have more serious impacts, but such compounds were not tested since they are not presently on the market in Washington State (or, apparently, in other western states).

5.1) Data relating to the quantifiable and non-quantifiable costs and benefits of the RV disposal station construction program were collected by mail surveys and by evaluating the first two years experience with such stations. The estimated annual cost is between $12,800 and $21,500 per dump station. However, this estimate is based on a number of tenuous assumptions the accuracy of which will be known only after several more years operating experience.

5.2) At present the revenue collected by a $1 fee per RV appears adequate to pay for the construction and maintenance of the 10 dump stations already in operation.

5.3) The disposal stations are very popular among RV owners and reasonably well-received by non-owners as well. Owners appreciate the convenience of the stations, and both groups applaud the potential public health benefits associated with the stations. Since approval of the program seems to go hand-in-hand with an understanding of its goals and funding mechanism, efforts should be made to educate the public about these things, especially at rest areas where disposal stations are constructed.

5.4) Most RV owners are willing to pay an extra $1 annually, i.e. $2 total, to maintain the program. If the cost goes above $2/year, support drops off. Non-owners of RVs are generally strongly opposed to subsidization of the program with funds not specifically collected from RV owners for this purpose.

5.5) Maintenance problems arising from improper use of the facility or vandalism are significant. At times these problems can lead to potential health hazards at the dump stations. While such problems cannot be eliminated entirely, providing proper signing, a convenient way to report problems, and frequent checking by maintenance personnel can minimize them.

5.6) Another category of facility misuse is dumping of large quantities of waste or toxic or hazardous waste. This is the largest and potentially most costly unknown aspect regarding the cost of the RV dump stations. These activities must be prohibited. The statutory basis for arrest and prosecution should be researched, and maintenance personnel and State Patrol instructed to watch for and stop any illegal use of the facilities.

5.7) Adequately staffing and funding for maintenance must be budgeted for the disposal station programs. Frequent, regular attention is needed to keep facilities sanitary; damage repair and maintenance most be performed promptly. Maintenance personnel should be consulted extensively for design suggestions to reduce operating problems at future dump stations.

# CHAPTER 1. INTRODUCTION AND REVIEW OF PREVIOUS WORK

## INTRODUCTION

In 1980, the Washington State Legislature passed HB1464 which provided for recreational vehicle (RV) wastewater disposal stations at selected Interstate Highway rest areas. The legislation also provided for a research study to evaluate the effects, costs and benefits of the disposal stations. This report is the product of that study, conducted at the Department of Civil Engineering, University of Washington, intended to characterize RV wastewaters and use of the disposal stations, to identify effects on treatment systems, and to determine costs and benefits of the disposal stations. The research study was originally defined by seven tasks listed in Table 1.1.

Table 1-1. Tasks Proposed for the RV Disposal Station Study

1. Review of pertinent literature and experience gained by other governmental and non-governmental units treating recreational wastewaters.
2. Evaluation of waste treatment systems at highway rest areas prior to construction of RV dump stations.
3. Evaluation of loading patterns at RV dump stations, including average and peak usage rates and average wastewater composition.
4. Performance evaluation of treatment systems receiving RV wastewater.
5. Toxicity testing of RV additive compounds exposed to aerobic and anaerobic bacteria and to algae.
6. Cost/benefit analysis of the RV dump station construction and operation program.
7. Management and reporting.

The research project has been closely coordinated with Washington State Department of Transportation (WSDOT) activities, especially with the construction and operation of the disposal stations. The rest areas chosen for the RV dump stations are shown on Figure 1-1. Selah Creek, north and southbound, Winchester, east and westbound, and Sprague Lake rest areas all use facultative lagoons for waste treatment. The Schrag rest area uses a septic tank/drainfield system and Sea-Tac, Silver Lake and Gee Creek, north and southbound, all ultimately dispose of their waste at municipal treatment plants. All stations were constructed in 1980 and 1981 and were opened in spring and summer 1981.

Figure 1-1. Locations of Recreational Vehicle Dump Stations at Washington State Highway Rest Areas

As the study progressed from June 1980 through December 1982, tasks outlined in Table 1 were completed with only minor modification. The studies encompassed a review of existing information which was summarized by Wong et al. (1981). The review included a literature survey, a questionnaire to Washington RV owners to obtain information about travel habits, size and number of holding tanks, use of preservative products, and a survey of other agencies' experience with RV waste disposal stations. Data were collected on the performance of a lagoon system at a rest area with a disposal station, a septic system receiving RV wastewater, and a municipal aerobic treatment system receiving RV wastes. Studies of the toxicity of preservative products and of the main ingredient, formaldehyde, were conducted with aerobic and anaerobic bacterial cultures and with an algal culture.

Extensive sampling of wastewater from RVs using disposal stations at highway rest areas was carried out to determine wastewater volumes and characteristics. This work has been reported in a Master's thesis by Kiernan (1982) addressing the toxicity of preservative compounds to waste treatment biota and another by Brown (1982), addressing the wastewater characterization and the effect on treatment systems. Automated and manual traffic counts were performed to ascertain intensity of disposal station use and the relation of disposal station to rest area use and to highway traffic. This work has been integrated into recommendations for design criteria for disposal stations treatment systems handling the RV wastewater.

A mail survey of RV owners and non-owners was conducted to assess awareness of the disposal stations and perceptions of the benefits or problems associated with them. Users of the disposal stations were also questioned about travel patterns. Finally, costs and maintenance and operation requirements have been assessed to complete the survey of benefits and costs of the program.

This report reviews all of these activities and is organized into five main sections: a review of previous work; use of rest area disposal stations and characterization of waste loadings; effects of formaldehyde-containing preservative compounds on organisms important in waste treatment; effects of RV wastes on treatment system operations; and costs and benefits of disposal stations at highway rest areas. The report is focused on those results of the study that can be implemented in planning, design and operation of the disposal stations.

## REVIEW OF PREVIOUS WORK

The use of motor homes, campers, and travel trailers with self-contained plumbing systems increased greatly during the 1960's and 1970's. Disposal of wastes is often an inconvenience to RV users, even though disposal facilities are provided at most campgrounds that accommodate RVs, at many RV service businesses and at some service stations. Illegal dumping of wastes along roadsides, to stormdrains, etc, is a significant public health and environmental concern. Free and convenient disposal stations at highway rest areas may both benefit RV users and reduce hazards from improper disposal.

Recreational vehicles vary widely in their water supply and waste holding tank capacities. Water supply tank sizes vary from 10 to 100 gallons. RVs with separate black (toilet) and gray (washwater) water systems have holding tank sizes that vary from 5 to 50 gallons for each tank. Often the capacity of the systems is not reached before dumping. This results in a smaller volume of waste, a relatively larger volume of rinse water, and a higher than specified concentration of preservative chemicals.

## Recreational Vehicle Wastewater

The volume of RV wastewater per vehicle has been measured by several researchers. Brestad et al. (1971) found that the average discharge of black and gray water was 25.1 gal./vehicle. In addition to this, approximately 15 gal. of rinse water was used. Pearson et al. (1980 a,b) estimated that 10 gal./vehicle of sanitary wastewater are released along with three gallons of rinse water. The time for the RV dump and rinse process has been estimated at 12-20 minutes (Brestad et al., 1971).

Two distinctive characteristics of RV wastewater are its high strength and the presence of preservative chemicals. These characteristics may preclude its treatment by conventional means with conventional wastewater treatment designs. Potential effects of RV wastewater on existing treatment systems include:

1. Toxicity from preservatives, reducing biodegradation;
2. Increased organic load;
3. Increased suspended solids load;
4. Deterioration of effluent quality.

## Wastewater Characteristics

Effective treatment systems for RV waste can be designed only with accurate data on the strength and composition of the wastewater. Pearson et al. (1980 a,b) studied RV wastes and their effects on septic tank-drainfield treatment systems. Watercraft wastes, closely related to RV wastes in strength and contents, were analyzed by Robins and Green (1974). They examined the aerobic treatablity of these wastes in activated sludge systems, complimenting Pearson's study of anaerobic treatability in septic tank systems. Additional information on RV and restroom wastewater characteristics has been gathered from reports by Brestad et al. (1971), Pfeffer (1974) and Sylvester and Seabloom (1972).

Characteristic values for water quality parameters of recreational wastewaters are summarized in Table 1-2. Black water is much more concentrated than gray water in both organic material and suspended solids, and typical combined black and gray water is more concentrated than restroom waste. Mean five-day biochemical oxygen demand ($BOD_5$) and suspended solids (SS) values reported by Pearson et al. (1980 a,b) were 11000 mg/L $BOD_5$, 7600 mg/L SS for black water and 1900 mg/L $BOD_5$, 745 mg/L SS for gray water. The combined waste had a $BOD_5$ of 3000 mg/L and SS of 3200 mg/L, much higher than the 160 mg/L $BOD_5$, 160 mg/L SS quoted for restroom waste with conventional plumbing. The combined $BOD_5$ of 3000 mg/L reported by Pearson et al. is much lower than would be obtained from mixing equal volumes of black and gray waters. This inconsistency may be due to large volumes of rinse water, poor estimates of the ratio of black to gray water actually dumped, and sampling inconsistencies.

Pearson et al. (1980 a,b) measured preservative concentrations in 14 black water composite samples in 1978 and 1979 and related them to experimentally determined bioinhibitory levels. Composite samples contained mean concentrations of 280 mg/L formaldehyde, 8 mg/L zinc, and 1.4 mg/L phenol, but the standard deviations of the samples were also very high: 310 mg/L, 13 mg/L and 1.2 mg/L, respectively.

## Preservative Compounds

Commercial recreational vehicle holding tank additives are intended to prevent or mask odors, to preserve holding tank waste prior to disposal, and/or to enhance liquefaction. The preservative chemicals have included formaldehyde, zinc sulfate, phenol, or quaternary ammonium salt base with blue

Table 1-2. Literature Values for Recreational Wastewater Composition

| Reference | Pearson et al. (1980 a,b) | Robins and Green (1974) | Sylvester and Seabloom (1974) | Metcalf and Eddy (1972) |
|---|---|---|---|---|
| Wastewater type | RV Combined | Powerboats, Sailboats, and Houseboats | Restroom Wastewater | Medium Domestic Wastewater |
| No. of Samples | 14(1) | 43 | 12 | |
| Volume, L (gal) per vehicle | 38 (10) | -- | | |
| TSS, mg/L | 3850 | 2430 | 165 | 220 |
| Standard Dev.[2] | 3630 | 980 | | |
| VSS, mg/L | 3330 | 1910 | | 165 |
| Standard Dev. | 3130 | 800 | | |
| COD, mg/L | 6210 | 6140 | 405 | 500 |
| Standard Dev. | 1710 | 1780 | | |
| $BOD_5$, mg/L | 3080 | 2560 | 165 | 200 |
| Standard Dev. | 2700 | 900 | | |
| Formaldehyde, mg/L | 18 | - | - | - |
| Standard Dev. | 31 | | | |
| Zinc, mg/L | 9 | 150 | - | - |
| Standard Dev. | | 100 | | |
| Phenol, mg/L | 0.5 | - | - | - |
| Standard Dev. | 0.8 | | | |

(1) 14 composited samples from 65 holding tanks.

(2) Standard deviation of reported values.

(3) Standard error of the mean value at a 95% confidence level.

dye and masking perfume added. At the concentrations specified in the manufacturer's instructions, these chemicals inhibit biological breakdown of the wastes for the holding period (generally 1-2 days). Chemical preparations that are intended to enhance waste liquefaction generally consist of a combination of enzymes and a pH buffer. Unlike the preservative-type chemicals they do not usually contain perfumes. The frequency of use of these products, their biodegradability or toxicity in treatment systems, and their persistence in the environment are questions directly related to the objectives of the project.

In the early and mid 1970's zinc was the most common active ingredient in additives (Brestad et al., 1971; Robins and Green, 1974; Pearson et al., 1980 a,b). In 1978, California prohibited the sale or use of zinc and other non-biodegradable additives. In response, manufacturers switched to other active ingredients, usually formaldehyde based. At present, the most popular RV holding tank additives are formaldehyde-based compounds. At the dosages specified by manufacturers (500-2000 mg/L) and for typical residence times in RV holding tanks, formaldehyde inhibits biological degradation and acts as a deodorant.

The concentration of formaldehyde in a holding tank is less than the initial dosage because formaldehyde reacts with many chemical components of the waste. Pearson et al. (1980 a,b) found wide variations in the formaldehyde concentrations in RV black water (276, std. dev. = 312 mg/L). These concentrations are sufficient to inhibit bioactivity. However, when black water samples are diluted with gray water, Pearson found that the mixed samples had a mean formaldehyde content of 18 mg/L (std. dev. = 31 mg/L).

Monomeric formaldehyde, a simple organic chemical (HCHO) is the active ingredient. It is available commercially either as formalin (formaldehyde +

alcohol) or paraformaldehyde, a solid which when solubilized yields monomeric formaldehyde. Formaldehyde can be degraded readily both aerobically and anaerobically at low concentrations (< 100 mg/L). However, there are conflicting reports in the literature on the concentrations at which formaldehyde becomes inhibitory to biological activity. Inhibitory levels differ with degree of acclimation, which may have varied in the different studies. In his handbook of environmental data Verschueren (1977) compiled data on formaldehyde (and other organic chemicals) from many different sources. He reported inhibition of anaerobic sludge digestion at 100 mg/L and inhibition of aerobic degradation at 135-175 mg/L formaldehyde. In contrast, acclimated activated sludge systems would withstand and oxidize formaldehyde concentrations of 333, 500 and 1500 mg/L. In a study of acclimation of anaerobic cultures to various petrochemical wastes, Chou et al. (1978) reported that anaerobic cultures could not acclimate to a 500 mg/L concentration of formaldehyde over 100 days of observation. Related compounds such as butyraldehyde were readily degraded within four days. These studies point out that biological treatment performance depends on type of treatment (aerobic or anaerobic), waste composition, and time of acclimation. Acclimation of micro-organisms to chemical additives is not significant in RV holding tanks because of short holding times but is of major importance in treatment systems involving extended biomass retention (septic tanks, facultative lagoons, municipal treatment).

Zinc sulfate and phenolics are toxic chemicals which were used in RV holding tank preparations; however, they are no longer used in commercial preservative products. Quaternary ammonium based preservatives, while still sold, are used much less frequently than formaldehyde products. Zinc concentration of 10 mg/L can inhibit biological activity in activated sludge systems (Robins and Green, 1974). A literature review on metal toxicity in anaerobic systems (Kugelman and Chin, 1971) revealed wide variation in reported zinc toxicity. Reported concentrations at which zinc inhibited anaerobic digestion were 350 and 1000 mg/L zinc. It was unclear in both of these studies whether the zinc concentrations reported represented total or soluble values.

Quarternary ammonium salt products are more stable under freeze/thaw conditions, are non-flammable, and can be more aesthetically scented than formaldehyde. They are, however, less biodegradable and are considerably more expensive than formaldehyde compounds. The mechanisms of their action and breakdown are unclear. They have been used extensively as bio-inhibitors in cooling tower applications and are effective at concentrations of 10-50 mg N/l.

Phenol-based preparations have also been used as biological inhibitors at manufacturer specified concentrations of 5 mg/L. Phenol can be easily biodegraded in acclimated systems. In a continuous feed anaerobic system with a mean residence time of 10 days, phenol removal approached 65% when dosed at concentrations ranging from 10-3000 mg/L (Pearson et al., 1980 a,b). Chou et al. (1978) found that batch anaerobic cultures could begin degrading phenol (initial concentration = 500 mg/L) after about a 7-day lag time at a steady average rate of 42 mg/L-d. When the phenol concentration was increased to 1000 mg/L, the acclimated cultures were able to degrade it at about the same rate.

The demand for biodegradable RV waste additives has increased the market for a relatively new type of additive, enzyme preparations. These are intended to enhance waste liquefaction through enzyme action and prevent clogging of black water lines. They are not deodorizers and cannot be used in recirculating toilets. One commercial preparation is a mixture of five different enzymes which are specific for certain materials - cellulose, other carbohydrates, proteins and fats. The time required for breakdown is 12-24 hours.

There is some doubt that the enzyme preparations are of any value in septic tank or other systems. The U.S. Public Health Service Manual of Septic Tank Practice (USPHS, 1969) discounted enzyme preprations as having no significant effect on waste liquefaction. Enzyme products would not be expected to have adverse effects on waste treatment.

In addition to these marketed RV products, some RV owners use commercial cleaners, like ammonia or Pine-sol$^R$, in their holding tanks through their effectiveness has not been documented. Pine-sol$^R$ is a commercial cleanser which contains pine oil as a main active ingredient (20%) along with octylmethyl and decyl-methyl chlorides. Inert ingredients include detergents and dyes. Commercial ammonia compounds generally contain a dilute ammonia solution with a scent. Ammonia is not generally a water pollutant; however, if necessary it can be converted to nitrate in aerobic systems through nitrification. Ammonia is beneficial to anaerobic systems at low concentrations but becomes inhibitory at concentrations greater than 1500 mg/L at high pH values or 3000 mg/L at near neutral pH values (McCarty, 1964).

## Treatment Systems for RV Wastes

Three treatment options are generally applicable for highway rest areas in Washington: evaporative lagoons, which require extensive algal activity to be effective; septic tank/drainfield systems, which depend on the activity of anaerobic micro-organisms; or connection to municipal systems with aerobic biological treatment. Information about formaldehyde in anaerobic and aerobic treatment systems has been summarized in the preceding section. Similar data were not found for algal systems. Design for and effects of treating concentrated RV wastes are well developed for aerobic systems (such as trickling filters or activated sludge) where BOD and suspended solids loading concepts are adequate. For septic system, Pearson et al. (1980 a,b) identified sludge and scum accumulation and inhibition of biodegradation as the critical concerns and developed a design procedure incorporating them. Information on algal systems is abundant - every sanitary engineering textbook includes some discussion on BOD loadings for pond systems - but inconclusive. Ponds are extremely variable from day to day in their response to loading and environmental conditions. The mechanisms are so complex and interactive that a detailed understanding is improbable. The criteria that have been developed are well represented by Hammer (1975), who states: "The maximum allowable loading is about 20 lb $BOD_5$ per acre per day in northern states to minimize odor nuisance in the spring of the year. In those climates where ice coverage does not prevail, higher organic loadings may be used; for example, in the south and southwest a loading of 50 lb per day per acre is practical. Retention time of waste water in the lagoon is 3 to 6 months depending on applied load and depth of waste water, evaporation rate, and loss by seepage." The criteria of 40 lb $BOD_5$/acre.d used as a check in the Highway Hydraulic Manual (WSDOT, 1972) is within this range and seems appropriate for remote locations in Eastern Washington.

## Other Concentrated Wastewaters

While there is extensive literature on disposal of septage and "night soil" (holding tanks for toilet waste contents), these wastes seldom contain preservative compounds and undergo considerable biodegradation before treatment. The information available is useful in a general way, but it is not directly transferrable to handling RV wastes. In a similar way, there is also information about wastes from recycling toilets (used in airplanes and trains) and chemical toilets (commercial portable toilets). However, these wastes are usually much more concentrated than RV wastes and their treatment also is not easily related to RV waste.

## Summary of Literature Survey

The literature review revealed basic information about the characteristics of RV wastewater and the preservative compounds used to avoid aesthetic nuisance. One study (Pearson et al., 1980 a,b) had performed a limited sampling program to find waste volumes and strengths and had found very high variability between samples. No information was available on frequency of use of rest area disposal stations. It was found that formaldehyde, the chemical predominantly used as active ingredient, was reactive with waste constituents, so the concentration in wastewater would be lower than the dosage added. Formaldehyde is also toxic to waste treatment microorganisms, but data are scattered and inconsistent. It is also biodegradable, often after a period of acclimation by a mixed culture. The literature survey revealed no information about algal lagoon systems receiving formaldehyde.

The initial literature survey pointed to several research questions and helped to clarify ones already identified. The principal questions were related to defining expected usage and loadings from RV disposal stations, effects of formaldehyde (and other waste constituents) on the treatment/disposal processes likely to be used at rest areas in Washington, incorporation of this information into a design basis for handling and treatment/disposal of disposal station wastes. In addition there were questions to be addressed related to the overall costs and benefits of the disposal stations.

## Agency Operating Experience

Several governmental agencies currently operate RV disposal stations at rest areas and parks. Eleven of the thirteen states in WASHTO (Western Association of State Highway and Transportation Officials) have disposal stations at highway rest areas. The Washington State parks and Recreation Department and the National Park Service have operated dump facilities in remote locations for many years. While none of these agencies (except Calfornia's Department of Transportation) have performed formal studies of RV wastewater effects on treatment processes, they all have compiled valuable operating data, which are summarized in this section.

### Wyoming

Wyoming's Department of Environmental Quality was contacted regarding RV waste treatability. Rest areas in Wyoming are usually equipped with small package treatment plants (e.g., extended aeration) which have higher operation and maintenance costs than the systems used in Washington. These biological treatment plants were affected detrimentally by chemical toilet loadings from RV dumps in the mid 1970s. The problem has abated somewhat in recent years perhaps due to decreased use of zinc-based products.

### Arizona

Arizona's highway department has more than 10 years of experience in managing RV disposal stations at rest areas. Combined RV and restroom wastes are treated in aeration ponds, lagoons, and septic tanks at various locations. A noticeable color change in the ponds has occurred in response to high loadings, generally during holiday use. Treatment disruption is sometimes severe enough to inactivate the lagoons so that control measures are necessary. Reseeding with commerically dried bacteria has been tried with reported success. The highway department indicated that some ponds have been reseeded several times. Mechanical aeration of the ponds has also been successsful in restimulating growth.

Septic tanks have appeared to be the most reliable systems. These have needed to be pumped out only once a year. However, the formaldehyde treated septage has been difficult to dewater when subsequently taken to a municipal plant.

### Montana

The Montana Highway Department is phasing out their RV disposal facilities. No new RV dump sites have been built since 1975. Maintenance problems and political pressure are cited as reasons for RV dump closue. There have been problems with people washing out stock trucks and horse trailers into dump stations; the resultant straw and debris have clogged the septic tank/drainfield systems. After eliminating RV dump facilities, the drainfield have not clogged. They presently pump out the septic tanks once a year.

Private campground owners have objected to the state providing free dump stations because it detracted from their potential business. They have lobbied to phase out rest area disposal stations.

### Nevada

The Nevada State Department of Transporation operates eight 2000 gallon septic tank systems at their rest areas. Most treatment systems in Nevada use separate septic tanks for restroom and RV waste, but there is one combined system. The septic tanks that receive only restroom waste need to be pumped out only once a year. Those receiving only RV waste need to be pumped out once each month. The combined waste system, which tends to have less use, needs pumping once every two months.

### Idaho

The Idaho Department of Transportation responded to an RV dump station questionnaire distributed by the Washington DOT in 1978. They indicated that all of their dump stations at rest areas were serviced by septic tanks and drainfield systems. Each system used two 1000 gallon tanks, which needed pumping every month during periods of high loadings. Idaho is moving toward closing these dump stations because of excessive maintenance problems associated with overloading and vandalism.

### California

The California Department of Transportation (Cal Trans) contracted with the University of California at Berkeley to study RV waste treatability in septic tank systems. Septic tank failures were attributed to poor design -- the tanks were too small to accommodate the high organic loading from RV waste and some soils had unexpectedly low percolation rates. Cal Trans also had problems with sewage lagoons due to hydraulic overloading.

### National Park Service

The National Park Service only operates RV disposal stations at large campgrounds, i.e., those with over 150 campsites. At such locations they anticipate that the RV dump wasteload is small in comparison to restroom waste. At large national parks like Olympic and Yellowstone there are sewage treatment plants which have a capacity of around 1 MGD. The operators of these plants have not noticed any problems associated with RV dumping.

Washington State Parks

The Washington State Department of Parks and Recreation operates RV disposal stations at many state parks. In their initial design of wastewater treatment facilities, the Parks Department assumed that RV waste would constitute such a small percentage of the total waste that it would have no impact on the treatment systems. Some of the park wastewater flows they considered were park residences, offices, day use campsites, trailer sites and tent sites. All lagoons and septic tanks treating combined RV, restroom, and assorted wastes were designed on this basis. The design department assumed that the park RV dump stations would not get on-off highway use. Discrepancies between these design estimates and actual flows may change the relative influence of RV dumping on the overall wastewater composition. However, RV dumping to date has not incapacitated any of the combined wastewater treament systems.

Parks with septic tank wastewater treatment system sometimes have totally separate systems for the RV wasteload, which elimates potential overloading off restroom treatment systems. At Washington State Parks there is a general policy of pumping out all the septic tanks once a year, but is is done more often if necessary.

# CHAPTER 2. RV WASTEWATER CHARACTERISTICS AND DISPOSAL STATION LOADINGS

The design of facilities for receiving and treating recreational vehicle wastes requires good estimates of waste loadings and characteristics. The literature reviewed in the previous section provides some basis for estimating volumes, characteristics and concentrations, but little for estimating usage of disposal stations at highway rest areas. Characterization of the quantity and quality of RV waste has been accomplished by sampling and analyzing tank contents, surveying users for information on additives used, and analyzing traffic patterns on the highway and at rest areas. In this section, these data are combined to provide a guide to the design loadings for disposal facilities in Washington.

## PRESERVATIVE USE

Preservative/deodorizing compounds and enzyme additives are widely used by RV owners and are selected from a wide variety of commercial products available from RV service businesses. In addition, household products such as perfumed cleaning compounds may be selected. Several RV businesses were visited in 1981 to determine the availability of additives. Representative products of all major types were purchased for testing. Most significantly, zinc and phenol based products were not available for sale in any of the stores visited.

Formaldehyde and paraformaldehyde products were available in many commercial formulations. Other types of additives, including enzyme containing products and some with unspecified ingredients, were fewer in number and higher in cost per use. Dealers were unable to provide information on the sales of specific products. Hence, RV users were asked which additive they were using during the RV wastewater sampling work of this study. Also,

Table 2-1. Frequency of Use of Various Types of RV Holding Tank Additives in Western Washington

| Active Ingredient | Number of Users | Percent |
|---|---|---|
| Paraformaldehyde | 68 | 38 |
| Formalin (formaldehyde solution) | 52 | 29 |
| None | 14 | 8 |
| Enzyme Formulations | 13 | 7 |
| Pine Oil with Surfactants | 12 | 7 |
| pH Buffers | 8 | 4 |
| Soap or Detergent | 5 | 3 |
| Quaternary Ammonium Compounds with Surfactants | 4 | 2 |
| Aspirin | 1 | < 1 |
| Zinc Sulfate | 1 | < 1 |
| Total | 178 | 100 |

questionnaires were to members of the Good Sams Club in Washington. The results of this survey are presented in Table 2-1 with preservatives grouped according to active ingredient. Two-thirds of the RV owners use formaldehyde preparations. A significant portion of the users was not using any additive. Usually, those people were on a short weekend trip. Phenol based products were not found either in this survey or on the shelves in retail RV accessories stores. Approximately ten percent of the RV owners were using household cleaners (usually Pine Sol or detergents). Only one user was found using a zinc based additive, and that product is no longer on the market. It has been replaced by a proprietary formulation under the same brand name.

The survey pointed to the importance of formaldehyde toxicity, biodegradability and persistence in any assessment of the impacts of RV wastewater. Other active ingredients are used infrequently, so their effective concentration in disposal station wastes will be very low. The most toxic and persistent compounds are no longer used at all.

## RV WASTEWATER CHARACTERIZATION

Wastewater from recreational vehicles was collected and sampled at RV disposal stations to determine average values and ranges for volume, composition of waste, and formaldehyde concentration. Fifty-four vehicles were sampled at the Sea-Tac Rest Area on Northbound Interstate 5 near Tacoma, Washington. Fourteen vehicles were sampled at the Silver Lake Rest Area on Southbound Interstate 5 near Everett, Washington. Five vehicles were sampled at the Thousand Trails Campground near LaConner, Washington.

The sampling apparatus that was used is shown in Figure 2-1. The RV owners usually discharge their holding tanks through a 10.2 cm (four-inch) diameter flexible plastic hose which is connected to the holding tank outlet.

Figure 2-1: RV Wastewater Sampling Equipment.

To collect waste as it was being dumped, a second hose was coupled to the owner's hose and connected to a heavy-duty, kitchen-style garbage disposal. The outlet of the disposal was connected with tygon tubing to a 19 L/min (5 gal/min) positive displacement, Vanton Flexiliner pump. The pump discharged into a 210 liter (55 gallon) barrel.

All black and gray water that the owner wished to dump, as well as any water that the owner used to rinse the holding tank and hose, was collected in the barrel. Thus, the sample had about the same composition as the water which the owner would typically discharge at an RV disposal station. The volume of total wastewater and rinse water was measured, and a 1.0 L (0.26 gal) sample was put on ice and brought back to the laboratory.

In the laboratory, a volume-proportional composite sample was created from between one and six individual samples. Composited samples were analyzed for total suspended solids (TSS, total nonfiltrable residue dried at 103 - 105° C), volatile suspended solids (VSS, volatile nonfiltrable residue at 550° C), total chemical oxygen demand (COD), soluble COD ($COD_s$), and total five-day biochemical oxygen demand ($BOD_5$) using Standard Methods (1975). Soluble COD samples were obtained by filtering the wastewater through a 0.45 μm membrane filter. Composited samples, filtered through a 0.45 μm membrane filter, also were analyzed for formaldehyde using the chromotropic acid method (Weiss, 1970).

A summary of the analytical results for RV wastewater characteristics is given in Table 2-2, and may be compared to those obtained in earlier studies (Table 1-2). Calculations for the average, standard deviation of the mean, and confidence limits for individual tank waste strengths are not straightforward because of compositing. The calculations are described in detail by Brown (1982).

Table 2-2. Characteristics of RV Wastewater Sampled During the Project

| | |
|---|---|
| Number of Samples | 72 |
| Volume, liters (gallons) | 62 ± 10(1) |
| standard deviation(2) | 43 (11) |
| Total Suspended Solids, mg/L | 3120 ± 490 |
| standard deviation | 2120 |
| Volatile Suspended Solids, mg/L | 2460 ± 410 |
| standard deviation | 1780 |
| Total COD, mg/L $O_2$ | 8230 ± 1430 |
| standard deviation | 6140 |
| Soluble COD, mg/L $O_2$ | 2930 ± 560 |
| standard deviation | 2350 |
| Total $BOD_5$, mg/L $O_2$ | 3110 ± 530 |
| standard deviation | 2200 |
| Formaldehyde, mg/L | |
| All RV Users | 170 ± 60 |
| standard deviation | 250 |
| Formaldehyde Additive Users Only | 250 ± 60 |
| standard deviation | 180 |

(1) Ranges given are the error of the mean value at a 95% confidence level.

(2) Standard deviation for individual RV samples.

RV wastewater is a very high strength waste. Variability in waste strength among vehicles is high as evidenced by the large standard deviations. Differences in RV facilities and user habits may be responsible for some of this variability. RV's with shower facilities and sinks may be expected to have more dilute wastes when large quantities of gray water are mixed with toilet wastes. Significant differences in the amount of time between dumping tank contents and hence in waste age exist. The volume of rinse water used also varies tremendously among RV users. Some do not rinse their tanks at all, and some use large quantities of rinse water.

Formaldehyde-based additives were used in two-thirds of the vehicles, and the wastewater from these vehicles had an average formaldehyde concentration of 250 mg/L. No analyses were made for active ingredients other than formaldehyde. None of the RV owners whose tanks were sampled were using phenol or zinc-based additives. As discussed earlier, zinc compounds apparently have disappeared completely from the commercial additive market, and use of phenol and quaternary ammonium-based products is low. The samples were not analyzed for enzyme compounds, since unambiguous analytical methods were not available, and it was felt that enzymes would have no potentially adverse effects on treatment systems.

The mean values obtained in this study are very similar to those of Pearson et al. (1980 a,b) and Robins and Green (1974) for suspended solids, COD and $BOD_5$. The confidence limits of the mean values are considerably tighter than those in the earlier studies, reflecting a larger number of samples (72) in the present study. The concentration of preservatives show the predominance of zinc-based additives in the early 1970's and the present use of formaldehyde. The difference in average waste volumes between our results and those of Pearson et al. (1980a,b) may be due in part to different sampling methods. Pearson et al. did not include rinse water in their volume measurements.

The standard deviation in all studies are very large, often approaching the mean value and illustrating the extreme variability of this kind of wastewater. The factors that result in variation in waste strength (and volume) include duration of trip or size of vehicle, availability of other restroom facilities, and preferences in frequency of holding tank dumping. However, despite the fact that the contents of an individual holding tank are not predictable within an order of magnitude for many constituents, the composite volume and loadings at a well used disposal station are probably predictable to within a factor of 50% based on the error of the mean values found in this study.

The loadings expected per vehicle are 190 g TSS, 150 g VSS, 510 g COD, 190 g $BOD_5$, and 11 g formaldehyde in 62 liters (16 gal.) of wastewater. These values form the basis for choosing design loadings for highway rest area disposal stations.

## FREQUENCY OF DISPOSAL STATION USE

Use of disposal stations at highway rest areas is highly seasonal with a large fraction of annual use occurring during the summer months and over holiday periods. Since design of most treatment and disposal systems depends primarily on loadings averaged over periods of a day to a week, most effort at estimating usage was devoted to short term manual and longer term mechanical traffic counts during the summers of 1981 and 1982. Table 2-3 lists the sites where counts were made, the type of count (mechanical or manual) and the period of record. The mechanical counter data base was obtained from loop counters specially spaced for this study as well as from permanent traffic counters in the DOT traffic data system. In some cases, interpolation between counters was used when counters were not close to the rest areas. In other cases, the data were fragmentary due to malfunction of counters.

Table 2-3. Mechanical and Manual Traffic Counting to Determine Frequency of Disposal Station Use.

| Highway | Rest Area | Location | Period of Record |
|---|---|---|---|
| Mechanical Counting 1982 | | | |
| I-5 | SeaTac | Highway Northbound | April 1 - July 11 |
| | | Rest Area | July 1 - July 11 |
| | | Disposal Station | April 1 - July 11 |
| I-82 | Selah Creek Northbound | Highway Northbound | April 1 - July 11 |
| | | Rest Area | April 1 - July 11 |
| | | Disposal Station | April 6 - July 11 |
| I-90 | Schrag | Highway | April 1 - July 11 |
| | | Rest Area | April 1 - July 11 |
| | | Disposal Station | April 1 - July 11 |
| I-5 | Gee Creek Northbound | Highway Northbound | June 1 - July 11 |
| | | Rest Area | June 1 - June 11 |
| | | Disposal Station | June 1 - July 11 |
| Mechanical Counting 1981 | | | |
| I-5 | SeaTac | Highway Northbound | July 6 - Sept 30 |
| | | Disposal Station | July 6 - Sept 30 |
| I-82 | Selah Creek Northbound | Highway Northbound | Aug 1 - Aug 31 |
| | | Rest Area | Sept 1 - Sept 18 |
| | | Disposal Station | Aug 1 - Aug 31 |
| I-90 | Schrag | Highway | Aug 1 - Sept 30 |
| | | Rest Area | Aug 1 - Sept 30 |
| | | Disposal Station | Aug 1 - Sept 30 |

| Highway | Rest Area | Location | Period of Record |
|---|---|---|---|
| Manual Counting 1982 | | | |
| I-5 | SeaTac | Rest Area, Disposal Station | 0800-1630 July 5 |
| I-82 | Selah Creek Northbound | Rest Area, Disposal Station | 1200-2000 July 5 |
| I-90 | Schrag | Rest Area, Disposal Station | 1000-1800 July 5 |
| Manual Counting 1981 | | | |
| I-5 | SeaTac | Rest Area, Disposal Station | 1000-1400 August 5 |
| | | Rest Area, Disposal Station | 1430-1730 August 8 |
| | | Rest Area, Disposal Station | 1200-1800 August 11 |
| | | Rest Area, Disposal Station | 1530-1830 Sept 7 |
| I-82 | Selah Creek, Northbound | Rest Area, Disposal Station | 900-1600 Aug 12 |
| | | Rest Area, Disposal Station | 1430-1830 Sept 7 |
| I-90 | Schrag | Rest Area, Disposal Station | 1300-1700 Aug 30 |
| | | Rest Area, Disposal Station | 1100-1400 Sept 3 |
| | | Rest Area, Disposal Station | 1200-1900 Sept 7 |
| I-5 | Silver Lake | Rest Area, Disposal Station | 1030-1630 Aug 16 |
| | | Rest Area, Disposal Station | 1000-1600 Aug 22 |
| | | Rest Area, Disposal Station | 1530-1830 Sept 7 |
| I-90 | Sprague Lake | Rest Area, Disposal Station | 1000-1500 Aug 15 |
| | | Rest Area, Disposal Station | 1000-1700 Aug 26 |
| | Winchester Westbound | Rest Area, Disposal Station | 1000-1400 Aug 22 |
| | | Rest Area, Disposal Station | 1015-1415 Aug 23 |

The data base for these Western Washington rest areas (SeaTac, Silver Lake, and northbound Gee Creek) is sufficient for determining patterns of seasonal and weekly use and maximum use rates. The four eastern Washington rest areas (northbound Selah Creek, Schrag, Sprague Lake and westbound Winchester) have also provided data that can be used to estimate disposal station use rates based on highway and rest area traffic.

The principal observation from the traffic survey for Western Washington that rest area and disposal station use are poorly correlated with highway traffic, since I-5 in the vicinity of Seattle (and to a lesser extent at Vancouver, WA) is dominated by commuters. Figure 2-2 shows highway traffic and disposal station use at the Sea-Tac rest area in May 1982. Highway traffic is at high levels from Monday through Thursday, peaks on Friday, and has minimum values on Saturday and Sunday. Disposal station use is fairly steady from monday through saturday, but peaks on sunday from rv users emptying holding tanks after weekend excursions. Hence, correlations with highway traffic must be viewed with much caution.

Disposal station use at SeaTac varies seasonally. Data from 1981 and 1982 are combined to show both the trend of weekly use and the maximum daily use (Figure 2-3). The use of the disposal station may be at maximum capacity for short periods at the end of holiday weekends and on Sundays during July and August. The maximum use rate observed was 14 vehicles per hour from 2-3 PM on Monday, July 5, 1982. Rates of 11 vehicles per disposal station per hour or higher occurred several times at SeaTac, but not at other rest areas. The highest daily use occurred after the three major summer holidays and was 230 dumps per day after Memorial Day and Independence Day and 190 dumps per day after Labor Day (totals include both disposal stations).

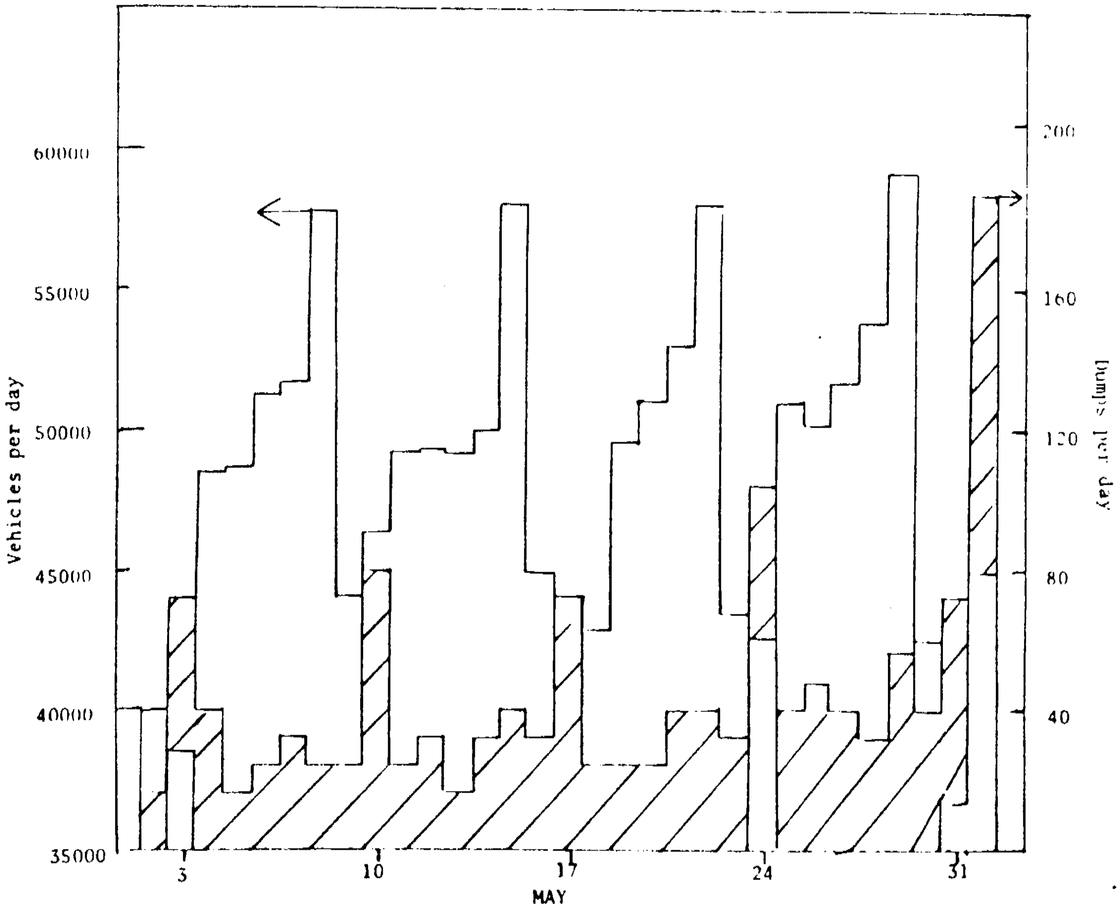

Figure 2-2. Daily Northbound I-5 Traffic and SeaTac Rest Area Disposal Station use for May, 1982.

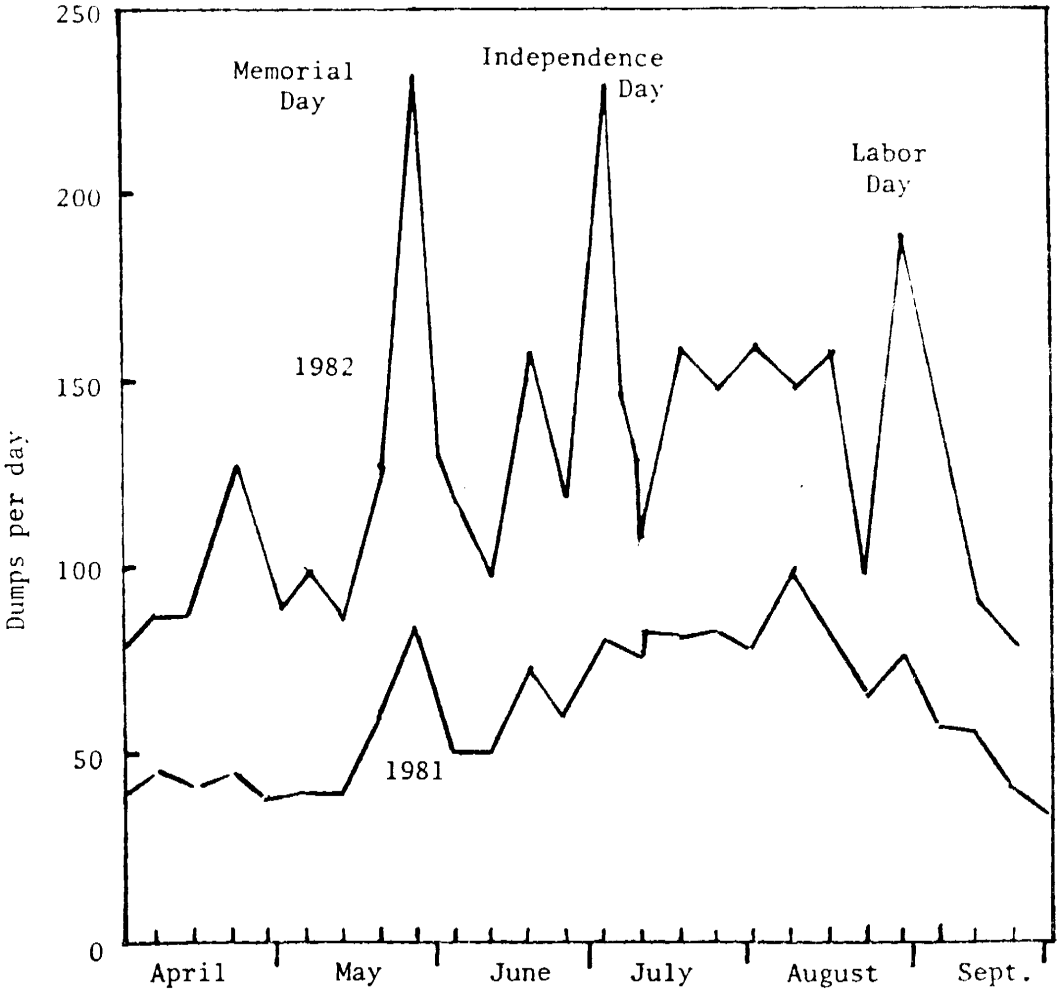

Figure 2-3. Disposal Station use at SeaTac Rest Area for 1981 and 1982 - Weekly Averages and Maximum Day.

For the time periods when highway traffic, rest area use, and disposal station traffic counts were available, the following averages were computed for summer, 1982.

| | Average Daily Traffic | Total Rest Area (% of ADT) | Disposal Station (% of Rest Area) |
|---|---|---|---|
| SeaTac, northbound | 52000 | 1700 (3.3%) | 60 (3.5%) |
| Gee Creek, northbound | 21000 | 1800 (8.6%) | 45 (2.5%) |

Between 2.5 and 3.5% of the vehicles using the rest area used the disposal station. Overall 0.1 to 0.2% of the highway vehicles used the disposal station.

Frequencies of use do depend on RV traffic, and on rest area use. About 30 hours of manual counts were made at Western Washington rest areas to obtain more information about frequency of disposal station use (Table 2-4). At SeaTac, Silver Lake and Gee Creek, 5% of the vehicles stopping at the rest area use the disposal station. Forty percent of the recreational vehicles stopping at the rest area used the disposal stations during our manual counts at these rest areas. Admittedly much of the manual counting was done at times when high disposal station use was expected, so this value is probably an upper limit. The values can be readily combined to compute that recreational vehicles constituted 13% of the rest area users, with values ranging from 7 to 31% during the periods of manual counting. Based on information about recreational vehicle travel, it is apparent that RV users are much more likely to use highway rest areas than other motorists. This trend is even more

Table 2-4. RV Disposal Station Usage Rates in Western Washington During Summer, Daylight Hours.

| | Number of Hours Counted | Number of All Vehicles Entering Rest Area per Hour | Number of RVs Entering Rest Area per Hour | Number of RVs Using Disposal Station per Hour (1) |
|---|---|---|---|---|
| Weekday | 6 | 92 | 9 | 2 |
| Weekend | 15 | 71 | 11 | 3 |
| Labor Day, 1981 | 7 | 104 | 27 | 8 |
| Independence Day, 1982 | 8 | 158 | 40 | 8 |

(1) There are two disposal stations at some Western Washington sites. The number given is the number of RVs per hour per disposal station.

apparent in Eastern Washington, away from the metropolitan centers and commuter traffic.

Disposal station use must ultimately be related to highway traffic. While the effects of commuter traffic are confounding, the pattern in summer in Western Washington is still worth stating. The observed rates at SeaTac increased from 0.09% in April and late September to 0.16% in the middle and late summer. Values at Gee Creek were between 0.25 and 0.3% in mid-summer. This factor (Disposal Station use to Highway Traffic) is not constant but depends mainly on the varying fraction of recreational travelers on the highway. A better but still imperfect factor is the fraction of Rest Area users who also use the disposal station. Values at SeaTac, Silver Lake and Gee Creek from both mechanical and manual counting ranged from 2% to 7% for non holiday periods. Four percent is a typical value. During peak holiday periods as many as 10% of the rest area users may use the disposal station facility.

In areas where commuter and commercial traffic obscures trends in recreational travel, ratios to highway use must be used very cautiously in estimating use of rest areas and disposal stations. The experience at such rest areas in Western Washington is that average seasonal use of disposal stations will not exceed four percent of the total rest area use. At the most used disposal station at SeaTac Rest Area, the weekly average use did not exceed 100 dumps/d, though the maximum daily rates reached 230 dumps/d (for two disposal stations) after two holiday weekends. Design for other rest areas along the I-5 consider in Western Washington can be based on experience at SeaTac and scaled by total rest area use.

In Eastern Washington rest area use and disposal station use rates are generally lower, reflecting lower highway traffic. The pattern of seasonal use is the same as shown in Figure 2-3, with disposal station use increasing by a factor of 3 from April to July, 1982, at Schrag and by a factor of 2 at Selah Creek Northbound. At Schrag the disposal station and the loop counter are adjacent to the exit from the rest area, and many vehicles pass through the disposal station unintentionally. Based on observations during manual counting periods, about half the vehicles passing the disposal station stop and use it. Therefore, we multiply the traffic loop count by 0.5 to estimate disposal station use. Data for the summer 1982 period (Table 2-5) show that daily traffic volumes yield very similar rates of rest area to traffic use (9.2 and 9.5%) and disposal stations to rest area use (6.9 and 6.7%). These ratios were surprisingly invariant for the weekly periods or even for individual days. They are considered to be a good basis for estimating disposal station use in Eastern Washington in areas uninfluenced by commuter traffic.

Table 2-5. Estimated Disposal Station Use at Two Eastern Washington Sites.

| | Total Daily Traffic veh/d | Rest Area Traffic, veh/d (% of ADT) | Disposal Station Use, No./d (% of Rest Area) |
|---|---|---|---|
| Selah Creek, NB | 3900 | 360 (9.2%) | 25 (6.9%) |
| Schrag, WB | 4700 | 450 (9.5%) | 30 (6.7%) |

Manual counts totalling 61 hours at four Eastern Washington rest areas are summarized in Table 2-6. The percentage of all vehicles at rest areas that were recreational vehicles during the manual counts was 16%. The fraction of RVs at the rest area that used the disposal stations was 19%, a value much lower than found in manual counts in Western Washington. The frequency of disposal stations use based on rest area traffic was 3%, which did not vary significantly for the different periods at the different rest areas. Apparently, a smaller fraction of the rest area users on weekends and holidays use the disposal station than over the active week since nearly 7% of rest area users are believed to use the disposal station based on mechanical traffic counters.

Maximum use rates were not very high (4-5 dumps per hour, less than 80 dumps per day); design of disposal station treatment facilities in Eastern Washington can be based on rest area traffic (6 to 7% of the total traffic or

Table 2-6. RV Disposal Station Usage Rates in Eastern Washington During Summer Daylight Hours.

| | Number of Hours Counted | Number of All Vehicles Entering Rest Area per Hour | Number of RVs Entering Rest Area per Hour | Number of RVs Using Disposal Station per Hour |
|---|---|---|---|---|
| Weekday | 17 | 35 | 4.3 | 1 |
| Weekend | 18 | 60 | 7.3 | 2 |
| Labor Day, 1981 | 11 | 47 | 6.1 | 2 |
| Independence Day, 1982 | 16 | 77 | 18 | 3 |

about 20% of the RV traffic that stop at a rest area will use the disposal station) or on highway traffic (about 0.6% will use a disposal station).

## LOADING ESTIMATION

Waste treatment systems should be designed for appropriate average and peak loadings. For lagoon and septic systems treating either combined restroom and disposal station or separate RV disposal station wastes, average loadings for the maximum months (July and August) are a sufficient basis to accomodate both maximum hydraulic flow over the few hours of capacity use and the maximum organic and formaldehye loadings that occur over holiday weekends. Design based on maximum months will ensure that problems of odors from excess BOD loading to lagoon or leachfield clogging will be avoided during those peak months. The systems will have some unused capacity at other periods.

For SeaTac and Selah Creek NB the design loadings are developed in the following calculations.

| | July-Aug ADT | x | Rest Area to ADT Ratio | x | Disposal Station to Rest Area | = | Disposal Station Use Per Day |
|---|---|---|---|---|---|---|---|
| SeaTac | 54000 | x | .05 | x | .03 | = | 80 |
| Selah Creek NB | 4000 | x | .10 | x | .06 | = | 25 |

The hydraulic and organic loadings associated with these design use rates are as follows:

| | SeaTac | Selah Creek NB |
|---|---|---|
| Volume | 5.0 $m^3/d$ (1320 gal/d) | 1.6 $m^3/d$ (423 gal/d) |
| TSS | 15.2 kg/d (33.5 lb/d) | 4.750 kg/d (10.5 lb/d) |
| VSS | 12.0 kg/d (26.5 lb/d) | 3750. kg/d (8270 lb/d) |
| COD | 40.8 kg/d (90.0 lb/d) | 12.8 kg/d (28.2 lb/d) |
| $BOD_5$ | 15.2 kg/d (33.5 lb/d) | 4.75 kg/d 10.5 lb/d) |
| Formaldehyde | 0.88 kg/d (1.9 lb/d) | 0.28 kg/d (0.62 lb/d) |

Other rest area loadings may be estimated in a similar fashion, using appropriate factors to arrive at disposal station use. In remote locations, approximately 10% of the highway traffic uses the rest area and 6% of the rest area users use the disposal station. Near population centers, both factors are lower and must be estimated with care. In these locations the fraction of rest area users using the disposal stations (3%) is reasonably valid, but the fraction of the ADT using the rest area is quite variable.

In some circumstances it may be desirable to estimate either maximum daily or maximum hourly loadings. These values, based on the maximum use rates observed at SeaTac, are tabulated below.

| | Max. Daily Loading (1) | Max. Hourly Loading (2) per Disposal Station |
|---|---|---|
| Flow | 14.3 $m^3$/d (3780 gal/d) | 0.68 $m^3$/hr (180 gal/hr) |
| TSS | 43.7 kg/hr (96.1 lb/d) | 2.1 kg/hr (4.6 lb/hr) |
| VSS | 34.5 kg/hr (75.9 lb/d) | 1.7 kg/hr (3.7 lb/hr) |
| COD | 117 kg/hr (257 lb/d) | 5.6 kg/hr (12 lb/hr) |
| $BOD_5$ | 43.7 kg/d (96.1 lb/d) | 2.1 kg/hr (4.6 lb/hr) |
| Formaldehyde | 2.51 kg/d (5.6 lb/d) | 0.12 kg/hr (0.26 lb/hr) |

(1) Based on 230 users/d.
(2) Based on 11 vehicles/disposal station/hr.

Maximum daily and hourly loadings at other disposal stations can be roughly scaled proportionate to the average design loadings. That is, at Sea-Tac the ratio of design use rate to maximum daily use rate is 80/230, or 0.35. Applying this ratio to Selah Creek, we estimate the maximum daily use rate to be 25/0.35, or 71 vehicles/d. The maximum hourly use rate at Sea-Tac is controlled not by availability of users, but by physical limitations on how fast an individual can enter, use, and exit the station. This limit would be the same at any station. Thus, we estimate the maximum hourly usage rate to be ((Maximum daily usage rate ÷ no. of disposal stations at the site) ÷ 8) or 11 vehicles/disposal station/hr, whichever is less. For Selah Creek NB, the estimated maximum hourly use rate is 8 vehicles/hr.

# CHAPTER 3: TOXICITY OF PRESERVATIVE COMPOUNDS

## BACKGROUND

The objective of the research described in this section was to determine the potential toxicity of RV additives to organisms important in biological waste treatment processes. Anaerobic and aerobic bacterial toxicity assays and the Selenastrum capricornutum algal toxicity assay were conducted. The toxic thresholds are compared to average additive concentrations in RV waste to evaluate whether toxic effects can be expected in waste treatment facilities receiving these wastes. These tests are intended to provide information useful in understanding the use of septic tank/drainfield disposal, evaporative lagoon and aerobic municipal treatment system for handling RV disposal station waste. Procedures to mitigate the toxic effects and ensure effective waste treatment are proposed.

## LITERATURE REVIEW

Large scale use of RVs and the concurrent problem of RV wastewater disposal are comparatively recent phenomena. Information on the biological effects of holding tank additives is limited and is complicated by the changeable nature of the market. California's ban of zinc-based additives in 1979 seems to have caused a shift toward formaldehyde based additives and enzyme products. Formaldehyde based additives presently dominate the market in Washington State.

### Reactions of Formaldehyde in Water

Monomeric formaldehyde (HCHO) is never present in large quantities in solution. It is chiefly present as methylene glycol and undergoes a series of polymerizing reactions in aqueous solution as shown below (Walker, 1964):

$$HCHO + H_2O \rightleftharpoons HOCH_2OH$$

$$2HOCH_2OH \rightleftharpoons HO.(CH_2O).H + H_2O$$

$$HOCH_2OH + HO.(CH_2O)_n.H \rightleftharpoons HO.(CH_2O)_{n+1}.H + H_2O$$

When $6 \leq n \leq 100$, the polymer may precipitate. This compound is paraformaldehyde, which is used in many powdered holding tank additives. Walker (1964) observed that it may take as long as five weeks for paraformaldehyde to dissociate in water at 18°C.

Formaldehyde is very reactive in solution and can combine with many components of a waste sample (Kitchens et al., 1976; Wolnak, 1971; Musterman and Morand, 1977). For instance, Fraenkel-Conrat and Ocott (1948) and Neely (1963b) studied the reaction of formaldehyde with several organic compounds at concentrations of a few millimolar and found that the reactions were complete within a few hours to a few days. Pearson et al. (1980a,b) cited a continuous culture experiment in which no biological activity was measured for 30 days, yet 80% removal of formaldehyde was noted. Chemical reactions are responsible for at least some removal of formaldehyde from wastewater solutions.

Tests were conducted with a composite sample of RV waste to roughly characterize formaldehyde removed from solution by physical and chemical means. The waste sample was spiked with formaldehyde to yield concentrations of 1070, 550, 300 and 275 mg HCHO/L. Both full strength waste and waste diluted to 50% of full strength were tested. One-tenth g HgCl/L was added to inhibit biological activity. Samples were placed on a shaker table and sampled for formaldehyde content after two hours and four days. The results are presented in Table 3-1.

Table 3-1: The Effects of Physical/Chemical Reactions on Formaldehyde Content of RV Waste.

| Sample | Formaldehyde Concentration (mg/L)<br>t = 0 | t = 2 hours | t = 4 days |
|---|---|---|---|
| RV waste | 1070 | 575 | 316 |
| RV waste | 550 | 310 | 315 |
| RV waste | 300 | 203 | 136 |
| 50% RV waste; 50% $H_2O$ | 270 | 208 | 95 |
| $H_2O$ (control) | 240 | 200 | 220 |

In samples containing RV waste approximately 25% to 50% of the initial formaldehyde was removed from solution within two hours, and 40% to 75% was removed within four days. Though the results from the replicate tests are not very precise, they are consistent with concentrations measured in the samples collected at the dump stations and are representative of the extent of non-biological formaldehyde removal in RV tanks and in treatment systems receiving RV wastes.

### Effects of Formaldehyde and Holding Tank Additives on Anaerobic Biodegradation

Pearson et al. (1980a,b) studied the potential effects of holding tank additives on anaerobic biodegradation by conducting toxicity assays with several compounds in additives including formaldehyde. These authors estimated a "half-kill dose" of 200 mg HCHO/L, at which anaerobic activity would be reduced by 50 percent.

Yang et al. (1979) conducted batch bioassays using a variation of the Anaerobic Toxicity Assay (ATA) described by Owen et al. (1979). These bioassays showed that formaldehyde caused increasing inhibition of biological activity at concentrations from 100 to 400 mg/L with apparent toxicity noted at 500 mg HCHO/L.

While Pearson et al., concluded that anaerobic organisms did not acclimate to formaldehyde, Yang et al. (1979) presented evidence of such acclimation in batch tests. The difference in the results is most likely due to inadequate cell residence time in the study by Pearson. The importance of cell residence time in such tests was demonstrated by Witt et al. (1979). They showed that full scale anaerobic filters which had very long cell residence times could achieve 98% removal of up to 5700 mg HCHO/L.

## Effects of Formaldehyde and Holding Tank Additives on Aerobic Biodegradation

Robins and Green (1974) examined the effects of watercraft holding tank additives on activated sludge. They conducted batch bioassays with unacclimated seed and found that the concentration of formaldehyde required for a given toxic response varied widely among additives. Components of the additives other than formaldehyde or reactions in solution which lower the effective formaldehyde concentration may account for some of the variation.

Gellman and Heukelekian (1950) used a Warburg respirometer to study the effect of formaldehyde on activated sludge. The toxic threshold for unacclimated bacteria fell between 130 and 175 mg HCHO/L. The authors developed an acclimated seed using enrichment techniques and were able to maintain a culture at 1750 mg HCHO/L.

Dickerson, et al. (1954) also used a Warburg respirometer to study the effects of formaldehyde bearing waste on activated sludge. When cultures were exposed to such waste for 48 hours, significant inhibition occurred between 125 and 187.5 mg HCHO/L. A second experiment was conducted with seed grown on this waste. The samples were buffered with $NaHCO_3$ and were able to oxidize up to 1000 mg HCHO/L without toxic effects.

Hatfield (1957) acclimated fill and draw cultures to 500 mg HCHO/L. Formaldehyde was removed within three hours, but it took significantly longer for the BOD to be reduced. Hatfield theorized that formaldehyde was first oxidized to formic acid before it could be completely metabolized.

Neely (1963a,b,c, 1966) examined the effect of formaldehyde on pure cultures of Aerobacter aerogenes and found that formaldehyde could be metabolized to $CO_2$. While concentrations of 20 and 50 mg HCHO/L did not affect resting cells, these concentrations could inhibit cell division. Several studies have been conducted to determine the effect of holding tank additives on sewage treatment plants. In a report prepared for the manufacturers of Inca Gold, a paraformaldehyde additive, Environomics International calculated "maximum and minimum effects" of formaldehyde additives on sewage treatment plants. They assumed that 175 mg HCHO/L was toxic to unacclimated aerobic bacteria and assumed an average holding tank contained 9 gallons of waste. They also assumed this waste contained the manufacturers recommended dose of Inca Gold, equivalent to 1046 mg HCHO/L. Maximum effect was defined as occurring when all the formaldehyde reaches the treatment plant (i.e., no physical, chemical or biological removal for formaldehyde in transit). Minimum effect was defined as occurring when 50% of the formaldehyde in the waste is removed through physical, chemical or biological processes prior to entering the treatment plant. With these assumptions, they estimated that an aerobic treatment plant could accept between five and ten tank loads per day per thousand gallons of sewage flow. They concluded that when acclimation of the microorganisms is considered, any negative impacts on treatment plant performance are unlikely. Wolnak (1971) made similar calculations for the bioassays showed that formaldehyde caused increasing inhibition of biological activity at concentrations from 100 to 400 mg/L with apparent toxicity noted at 500 mg HCHO/L.

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## Effects of Formaldehyde and Holding Tank Additives on Algal Populations

Little literature is available examining the effects of holding tank additives on algal populations. Verschueren (1977) quotes data gathered by Bringman and Kuhn (1976) who found formaldehyde to be toxic to *Scenedesmus* at concentrations between 0.3 and 0.5 mg HCHO/L and claim that multiplication of *Microcystis aeruginosa* is inhibited at 0.39 mg HCHO/L. According to Kitchens, et al. (1976), Helms found that *Scenedesmus*, *Sirogonium*, *Spyrogyra* and *Stigeoclonium* died at formaldehyde concentrations between 6 and 20 mg HCHO/L. Although these studies do not provide definitive information about toxicity of formaldehyde to algae, it is interesting to note that the reported toxic thresholds are considerably lower than those for aerobic or anaerobic bacteria.

## Effects of Non-Formaldehyde Additives on Biological Waste Treatment

The wide variety of non-formaldehyde additives used by RV owners necessitates that any evaluation of their effects be done on an individual basis. Requests for information from manufacturers are often answered with claims that the ingredients are proprietary. After formaldehyde based additives, preparations composed of organic enzymes seem to be most popular in Washington State. No published work evaluating these compounds is currently available. One additive has been found which contains sodium oxalate. Verschueren (1977) quotes Brigmann and Kuhn's determination of a toxic concentration to *M. aeruginosa* as 42 mg/L as oxalic acid. Ludzak and Ettinger

(1960) found that a fill and draw activated sludge unit can give 99% removal of oxalic acid at 333 mg/L.

Other studies (Pearson, et al. 1980a,b; Robins and Green, 1975) have evaluated the effects of zinc sulfate, phenol and quaternary ammonium additives. Since these compounds were not used by any of the RV users surveyed, they were not investigated.

## EXPERIMENTAL PROCEDURES FOR TOXICITY ASSAYS

Field surveys of RV users and chemical analyses of holding tank contents were conducted to determine which types of additives were most commonly used by RV owners in Washington State. Additives were ranked by frequency of use and grouped by their active ingredients. Commercial additives were purchased, mixed to manufacturers' specifications based upon an assumed tank volume, and tested in the laboratory for Chemical Oxygen Demand and, for those additives with formaldehyde as the active ingredient, for formaldehyde content. Toxicity assays were conducted with the most common additives from each of the groups.

RV owners were surveyed and holding tank contents were collected and analyzed between December 1980 and September 1981. The sampling program was conducted at the Sea-Tac and Silver Lake rest areas, Wenberg State Park, and at a private campground near LaConner, Washington. Surveys were used to gather information regarding types and quantities of additives used, frequency of RV use, holding tank wastewater disposal practices, and RV user opinions regarding dump station design.

RV holding tanks were sampled and analyzed for formaldehyde content by color development with chromotropic acid (Weiss, 1970).

## Anaerobic Toxicity Assays

Anaerobic toxicity assays (ATAs) were conducted using the method of Owen et al. (1980). ATAs are batch bioassays in which a series of test bottles are prepared containing a defined medium, an inoculum of anaerobic bacteria, a spike of organic feed with known COD consisting of acetate and propionate, and a toxicant dose. Anaerobic degradation of the feed is indicated by production of methane and carbon dioxide. Toxicity is defined as any reduction of gas production compared to predicted values or to a toxicant free control. Seed blanks are run without organic additions to correct for the effect of COD added in the inoculum.

A mesophilic anaerobic culture was maintained with 40 day hydraulic and solids retention time. The reactor was fed 100 ml (0.026 gal) per day of a solution containing the nutrients listed in Table 3-2. A mixture of Aquakem and L-10, two formaldehyde based additives, was gradually substituted for the feed until the reactor was receiving 60 ml (0.015 gal) additive mix, 40 ml (0.011 gal) nutrient solution. The loadings of COD and formaldehyde were 660 mg/L-d and 8 mg/L-d respectively.

ATAs were conducted in serum bottles which had been acid washed, rinsed with deionized distilled water and flushed with a carbon dioxide-nitrogen gas mixture to remove any atmospheric oxygen. Nutrient media, anaerobic bacterial culture, some easily degradable organic matter, and varying amounts of the test compound were added to the purged serum bottles, and the bottles were placed in a 34°C incubator. After one hour equilibration, any pressure in excess of atmospheric in the bottle was released, and the assay was begun.

Gas production was measured using glass syringes. Final cumulative gas production was analyzed for significant differences between sets of replicates within an assay by a one way analysis of variance (Zar, 1974).

Table 3-2. Nutrients Present in Culture Media for Anaerobic Toxicity Assays and Algal Assays.

| Compound | ATA Media | Algal Assay Media |
|---|---|---|
| $(NH_4)_2PO_4$ | x | o |
| $K_2HPO_4$ | o | x |
| $NaNO_3$ | o | x |
| $CaCl_2 \cdot 2H_2O$ | x | x |
| $NH_4Cl$ | x | o |
| $NaHCO_3$ | x | x |
| $MgCl_2 \cdot 6H_2O$ | x | x |
| $KCl$ | x | o |
| $MnCl_2 \cdot 4H_2O$ | x | x |
| $CoCl_2 \cdot 6H_2O$ | x | x |
| $H_3BO_4$ | x | x |
| $CuCl_2 \cdot 2H_2O$ | x | x |
| $NaMoO_4 \cdot 2H_2O$ | x | x |
| $ZnCl_2$ | x | x |
| $FeCl_2 \cdot 4H_2O$ | x | o |
| $FeCl_3 \cdot 6H_2O$ | o | x |
| $MgSO_4 \cdot 7H_2O$ | o | x |
| $Na_2S \cdot 9H_2O$ | x | o |
| $Na_2EDTA \cdot 2H_2O$ | o | x |
| biotin | x | o |
| folic acid | x | o |
| pyridoxine hydrochloride | x | o |
| riboflavin | x | o |
| thiamin | x | o |
| nicotinic acid | x | o |
| pantothenic acid | x | o |
| $B_{12}$ | x | o |
| p-aminobenzoic acid | x | o |
| thioctic acid | x | o |
| resazurin | x | o |

## Aerobic Toxicity Assays

Aerobic toxicity assays were conducted with an electrolytic respirometer (Exidine, Inc., Model ER-100, Colorado Springs, Colorado). The respirometer generates oxygen to replace that consumed by microbial action so as to maintain a constant partial pressure of oxygen in the atmosphere above the test solutions.

The seed culture for the aerobic assays was maintained with a 36-hour hydraulic detention time and a 30 day solids retention time. The organic loading was 200 mg COD/L-d Simulac, an infant formula (Meade Laboratories). The culture was gradually acclimated to an Aquakem/L-10 mixture which contributed an additional 60 mg HCHO/L-d (120 mg COD/L-d). When growth in the reactor became dominated by filamentous bacteria, the feed was supplemented with 100 mg/L-d of ammonium chloride.

The aerobic assays were conducted by adding settled seed, inorganic nutrients, $O_2$-saturated dilution water, enough Simulac to give a COD of 200 mg/L, and varying concentrations of additives to an assay bottle. The bottles were connected to the respirometer in a 20°C constant temperature room, and $O_2$ consumption was recorded at three hour intervals.

Toxicity was assessed by comparing oxygen consumption in test reactors with that in the control. If the test bottle had oxygen consumption significantly less than the control or if there was a significant lag in the onset of oxygen consuption, toxicity was indicated. Oxygen consumption in a test bottle in excess of that in the control indicated the additive was being oxidized.

## Algal Assay Bottle Test

The Algal Assay Bottle Test (AABT) was conducted using a modification of the procedure suggested by Miller et al. (1978). This assay is based upon the assumption that given optimal light, temperature and atmospheric conditions, and in the absence of toxic effects, the amount of algal growth is determined by the nutrient concentration of the media. Toxicity is evaluated by adding identical media and algal populations to a number of flasks, then spiking the flasks with a test compound. Toxicity is indicated if the test flasks fail to produce the same concentration of algal cells dry weight as unspiked controls.

*Selenastrum capricornutum*, the accepted test alga for the AABT, was used in these tests. Nutrient medium was prepared by diluting 1 ml of the nutrient solutions specified by Miller et al. (1978) to 1 liter with deionized distilled water. Nitrogen in the form of $NaNO_3$ and phosphorus as $K_2HPO_4$ were added to yield concentrations of 2.63 mg N/L and 0.116 mg P/L. This adjustment in the nutrient media was made to reflect the nutrient-rich conditions in sewage treatment lagoons. After nutrient addition, the media was filter sterilized by passing the solution through 0.45 µm Millipore filters. Media content is given in Table 3-2. The algal assays were conducted in flasks which had been acid washed, neutralized, rinsed and autoclaved. Each flask in an assay had an equal amount of media, a variable amount of 0.45 micron-Millipore filtered additive and enough ultrapure water to give a final volume of 50 ml (0.013 gal). A volume of inoculum containing 80,000±10% cells was added to each flask. Flasks were placed on a shaker table and agitated constantly. They were kept at 24±2°C and exposed to 3800±380 lux. The predicted yields for the assay flasks are 50 mg *S. capricornutum*/L. Actual dry weight concentrations were calculated on day 10 of the AABT based upon cell counts and mean cell volume (MCV).

Data were reduced to milligrams per liter dry weight S. Capricornutum assuming a mean cell density of $3.6 \times 10^{-10}$ mg/$\mu^3$ (Miller et al., 1977). Data were analyzed for significant differences between sets of replicates within an assay by a one way analysis of variance (Zar, 1974).

## RESULTS AND DISCUSSION

### RV Holding Tank Additives

RV users were surveyed in person at highway rest areas and by mail, with the cooperation of the Washington State Good Sam Club (an association of RV owners). Among other items, the questionnaires requested that the respondents identify the type of additives used in their holding tanks. Additive manufacturers were contacted and many supplied useful product information. Additives were purchased, mixed to manufacturer's specifications and tested for COD and, where appropriate, formaldehyde content. Manufacturers' recommended doses indicate a given amount of additive should be mixed to a known tank volume. This is generally four ounces per ten gallons of waste (3.12 ml/L) for liquid additives, and one package or tablet per 5, 10, or 20 gallons for solid additives. Since RV users may not know the volume of waste in their tank, actual additive concentrations may be higher or lower than manufacturer's recommendations.

Survey and analytical results are summarized in Table 3-3 and fall into six additive categories:

1. Formaldehyde based additives
2. Paraformaldehyde additives
3. Enzyme based additives
4. Sodium oxalate additives
5. Unidentified or non-commercial additives
6. Additive free

Table 3-3: Chemical Characteristics of Several RV Holding Tank Additives

| Additive | Recommended Dose | Active Ingredient | Recommended(2) Formaldehyde Concentration | COD | Number of Users |
|---|---|---|---|---|---|
| Aquakem | 3.12 ml/L | Formaldehyde | 830 mg/L | 1640 mg/L | 37 |
| Campa | -- | -- | -- | -- | 2 |
| Odor-John | -- | " | -- | -- | 1 |
| Travel-John | 3.12 ml/L | " | 120 | 840 | 1 |
| L-10 | 3.12 ml/L | " | 830 | 1600 | 3 |
| Inca Liquid Gold | 3.12 ml/L | " | -- | 2930 | 1 |
| Sani Majik | 3.12 ml/L | " | 1020 | 1580 | 1 |
| Potty Chem | 3.12 ml/L | " | 110 | 570 | 6 |
| Drikem | 2140 mg/L | Paraformaldehyde | 1100 | 2200 | 6 |
| Reliance | -- | " | -- | -- | 1 |
| Monochem(1) | -- | " | 605 | 1240 | 10 |
| Inca Gold | 1630 mg/L | " | 980 | 1540 | 13 |
| T-5 | 1690 mg/L | " | 980 | 1540 | 34 |
| PTC | 2140 mg/L | " | 940 | 1700 | 4 |
| Wastaway II | 160 mg/L | Sodium Oxalate | -- | 25 | 5 |
| Trailerzyme | 750 mg/L | Enzyme | -- | 122 | 5 |
| RV-Trine | -- | " | -- | -- | 1 |
| Potty Fresh | -- | -- | -- | -- | 1 |
| PR-5 | -- | -- | -- | -- | 1 |
| Blue John | -- | -- | -- | -- | 1 |
| Parchem | -- | -- | -- | -- | 1 |
| Aquafresh | -- | -- | -- | -- | 1 |
| Modern Camper | -- | -- | -- | -- | 1 |
| A-33 dry | -- | -- | -- | -- | 2 |
| Break-up Plus | 1.56 mg/L | -- | -- | -- | 1 |
| Pinesol | 1 cup | -- | -- | -- | 12 |
| Ivory Detergent | -- | -- | -- | -- | 1 |
| Soap | -- | -- | -- | -- | 4 |
| Lysol | -- | -- | -- | -- | 4 |
| Baking Soda | -- | -- | -- | -- | 3 |
| Aspirin | -- | -- | -- | -- | 1 |
| None | -- | -- | -- | -- | 14 |
| | | | | | 180 |

(1) Monochem is the manufacturer of both PTC and T-5.

(2) Based on recommended dose and concentration of formaldehyde in formaldehyde-and paraformaldehyde-based additives.

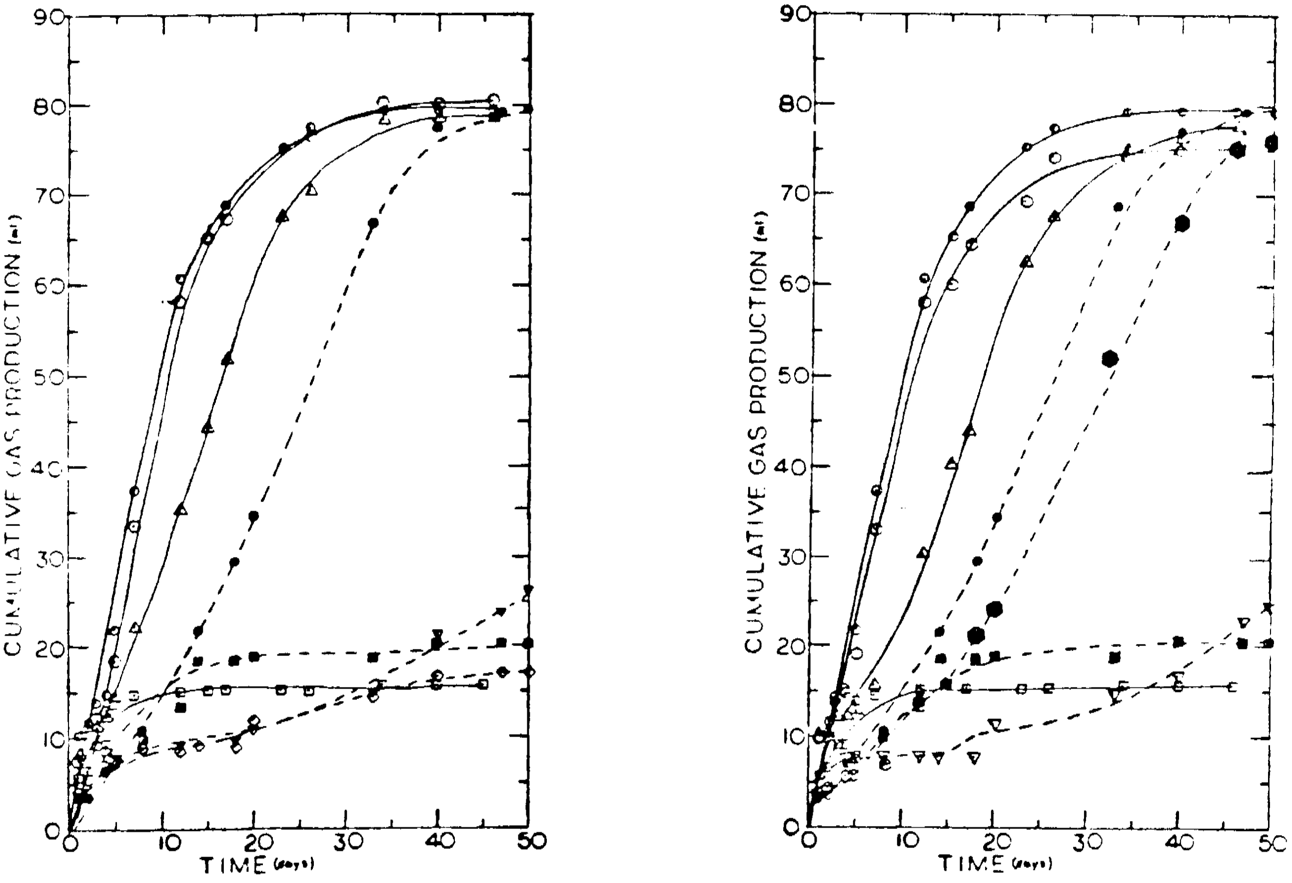
Formaldehyde and paraformaldehyde products were used by two-thirds of those surveyed, clearly dominating the market. The COD to formaldehyde ratio in these additives in every case is greater than the value of 1.07 mg COD/mg HCHO ratio expected for a pure formaldehyde solution. In addition to the active ingredient, these additives contained 2 to 5% surfactants, 1 to 4% dye and 12 to 40% inert ingredients. Each of these components may contribute to the COD. All formaldehyde and paraformaldehyde additives analyzed contain a blue dye with an absorbance peak at 630 nm. The enzyme products contained a variety of organic enzymes, buffers and dyes. The manufacturer of Wastaway II, the sodium oxalate additive tested in bioassays, did not supply product information, so other ingredients are unknown.

## Anaerobic Toxicity Assays

The products tested in the toxicity assays were the most popular additive in each of the four classes of commercial additives, based on survey results presented in Table 3-3. The products tested were Aquakem, a formaldehyde additive, T-5, a paraformaldehyde additive, Trailerzyme, an enzyme additive, and Wastaway II, a sodium oxalate additive. Reagent grade formaldehyde was also tested to determine if it was responsible for toxicity observed in formaldehyde-based additives.

Typical results for ATAs conducted with these additives are presented in Figure 3-1. In the figure, cumulative average gas production is plotted against time from initiation of the assay.

The total gas production expected in an assay bottle can be calculated assuming 0.35 ml methane is produced per mg COD (McCarty, 1964) and 0.5 ml carbon dioxide is produced per ml $CH_4$ (Owen et al., 1980). Final net gas production is calculated by subtracting gas produced in seed blanks from the



| Dose | Expected Gas Production | HCHO |
|---|---|---|
| ◇ 25% | 278 ml | 208mg/l |
| ▽ 15 | 192 | 125 |
| △ 10 | 149 | 83.2 |
| ⬡ 1 | 71.7 | 6.3 |
| ● ○ Control | 63.1 | 0 |
| ■ □ Seed Blank | 0 | 0 |

| Dose | Expected Gas Production | HCHO |
|---|---|---|
| ▽ 10% | 144 ml | 96.2 mg/l |
| △ 5 | 104 | 49.1 |
| ⬢ 2.5 | 83.3 | 24.6 |
| ○ 0.5 | 67.1 | 4.4 |
| ● ○ Control | 63.1 | 0 |
| ■ □ Seed Blank | 0 | 0 |

Figure 3-1: Anaerobic Toxicity Assays of (a) Aquakem (Active Ingredient: formaldehyde) and (b) T-5 active ingredient: Paraformaldehyde). Solid and broken lines represent data from ATAs started on different days. Dose based upon manufacturer's recommendation of 8 oz. per 20 gallons of waste. Expected gas production based on degradation of test compound.

total gas produced. The predicted, net gas production in control bottles is 63.1 ml total gas per bottle. ATAs were terminated after controls produced no gas for several days.

Aquakem (active ingredient: formaldehyde) caused a sharp increase in toxicity as the dosage was increased from 10% to 15% of the manufacturer's recommended dose (Figure 3-1a). The 10% dose slightly inhibited gas production causing a lag of about four days compared to the blank. The 15% dose caused extreme inhibition although acclimation appeared to have taken place after 25 days. A dose of Aquakem equivalent to 25% of the recommended dose caused extreme toxicity. Gas production in assay bottles exposed to a 25% dose of Aquakem stopped prior to the termination of the assay. Final gas production was less than that measured in seed blanks.

ATAs conducted with T-5, a paraformaldehyde additive, are summarized in Figure 3-1b. Doses of T-5 up to the equivalent of 5% of the manufacturer's recommendations had no effect on final cumulative gas production. A quantity of T-5 equivalent to 10% of the recommended dose caused extreme inhibition, although acclimation appeared to be occurring 30 days after the start of the test. Replicates exposed to a 10% dose of T-5 were still producing gas at the termination of the assay.

Figure 3-2 summarizes the results of an ATA conducted with reagent grade formaldehyde (MCB Labs, Inc.). Concentrations of 243, 162, 81, 40.5 and 8.1 mg HCHO/L were tested. These are approximately equivalent to the formaldehyde concentrations in 40%, 20%, 10%, 5% and 1% doses of Aquakem. Figure 3-2 clearly illustrates the increasing toxicity and inhibition caused by increasing doses of formaldehyde. A dose of 8.1 mg HCHO/L had no measureable effect on gas production. Intermediate doses of 40.5 and 81.0 mg HCHO/L caused increasing inhibition of gas production. Acclimation occurred at approximately

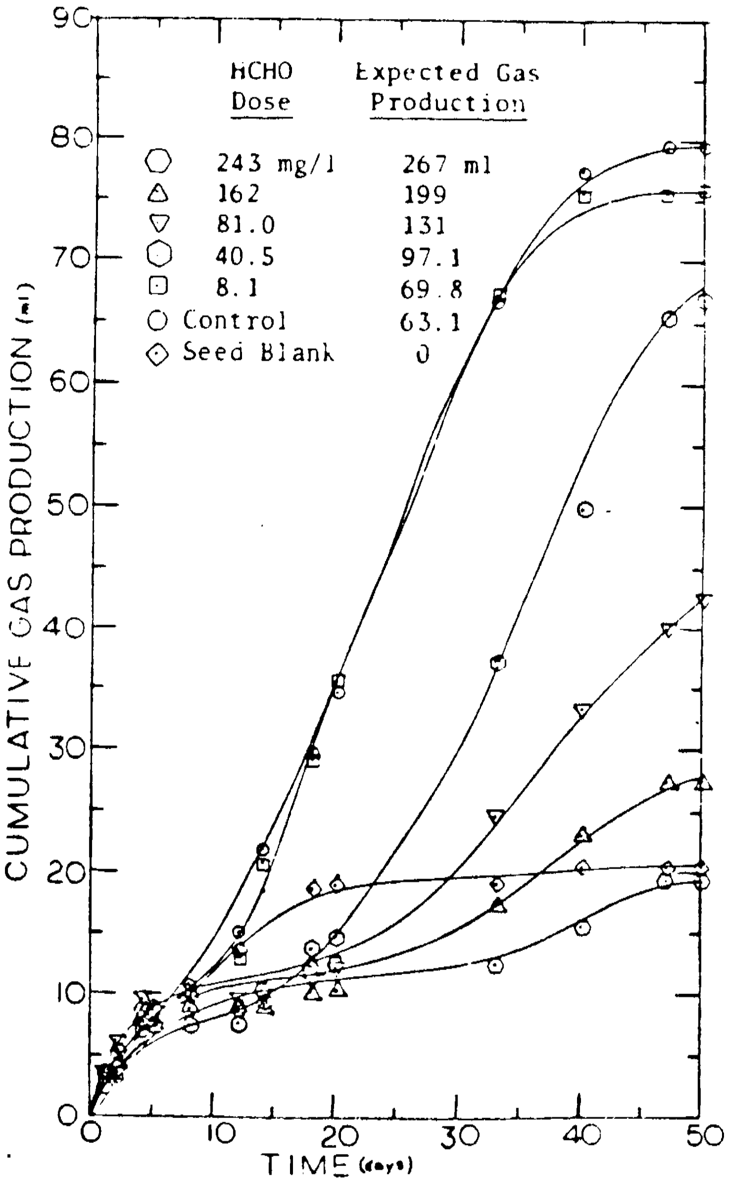


Figure 3-2: Anaerobic toxicity assay of formaldehyde. Expected gas production calculated as per Figure 3-1.

day 20 and day 25 respectively, and at day 50 both of these doses were still producing gas. Doses of 162 and 243 mg HCHO/L were apparently toxic to anaerobes with gas production in both cases stopping far short of predicted levels. None of the replicates for either dose produced any additional gas for the last three days of the assay.

Figure 3-3 provides a summary of the ATA data from Aquakem, T-5 and formaldehyde assays. Normalized gas production, defined as sample gas production divided by control gas production, is plotted against additive dose in terms of formaldehyde content. The data show quite clearly that at concentrations equivalent to between 50 and 100 mg HCHO/L there is a sharp increase in the effect of formaldehyde on anaerobic batch cultures as measured by the ATA. All assays demonstrated nearly 90% reduction in gas production at concentrations equivalent to between 100 and 150 mg HCHO/L. The degrees of inhibition noted in the different assays cannot be compared with any confidence as each assay may have been started with different numbers of organisms. Chou, et al. (1978) noted that population dynamics may cause the time of acclimation to a given compound to vary from trial to trial, making comparisons of lag times noted in separate assays inadvisable.

The data for ATAs of the Wastaway II (active ingredient: sodium oxalate) and Trailerzyme (active ingredient : enzymes) have been presented by Kiernan (1982). For both additives the 95% confidence intervals for controls and all additive concentrations overlap, indicating that these additives had no discernible effect on the test organisms. Thus oxalate- and enzyme-based additives are not toxic to anaerobic organisms at any concentrations likely to be found in treatment systems.

Formaldehyde based additives can be toxic to anaerobic bacteria at between 100 and 150 mg HCHO/L, which is roughly half the concentration found

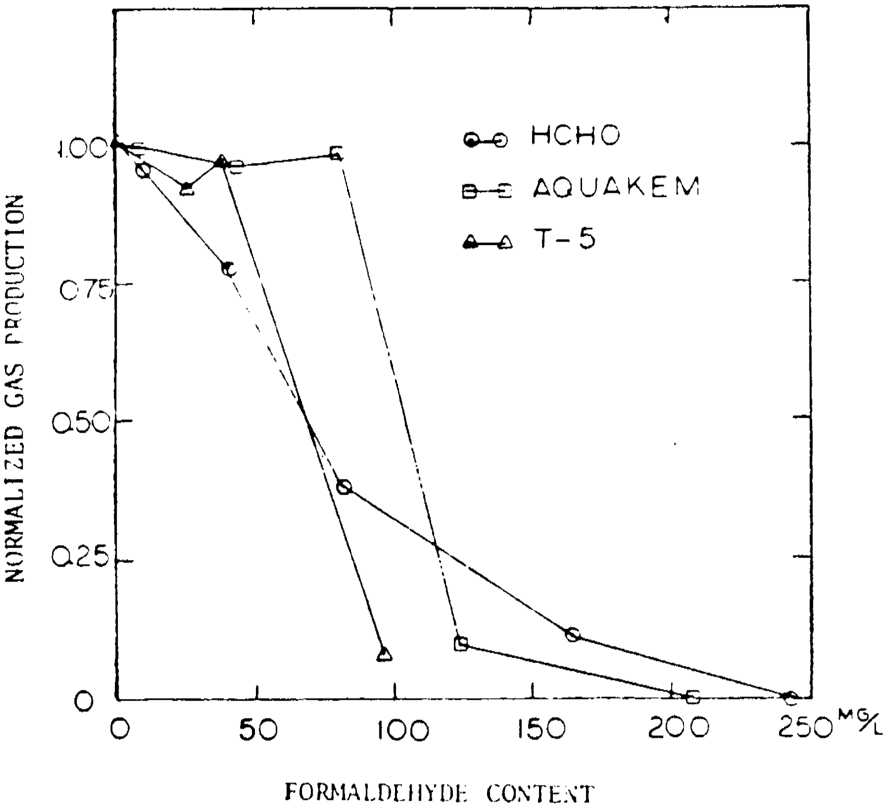


Figure 3-3: Anaerobic toxicity assay data summary for Aquakem, T-5 and Formaldehyde: Normalized gas production vs. formaldehyde concentration. Normalized gas production defined as sample gas production divided by control gas production at the termination of the assay.

in RV waste. The bacteria used as seed had been acclimated to 8 mg HCHO/L. The results are consistent with batch results reported by Pearson et al. (1980a,b). Yang et al. (1979) reported anaerobic batch cultures acclimated to concentrations of 250 and 400 mg HCHO/L within ten days in ATAs they conducted. However, they used approximately 10 times as much seed as is called for in the standard procedure. The additional biological solids may have combined with some of the formaldehyde and lowered its effective concentration in Yang's experiments.

It is impossible to determine with confidence if any of the additives tested was degraded biologically. In every case where sample gas production exceeded the controls, the difference was not significant at the 95% confidence level. To evaluate biodegradability, one must either use a larger number of replicates or a different method. Owen et al. (1979) suggest a modification of the ATA called the Biochemical Methane Potential Test for this purpose.

## Aerobic Toxicity Assays

Aerobic toxicity assays were conducted with the same additives as used in ATAs. The results of these assays are summarized in Figures 3-4 through 3-6. These figures are plots of cumulative oxygen consumption versus time for individual reactors. An additive concentration was defined as toxic if the final oxygen consumption was significantly less than that of the control. An additive was defined as inhibitory if its initial lag period was longer than that of the control in that assay. The lag period was defined as the amount of time required for $O_2$ consumption to reach 10% of the final oxygen consumption of the control in that assay.

Aquakem (active ingredient: formaldehyde) caused no significant toxicity at any of the dosages tested (Figure 3-4). The lag periods for the control, 10%, 50% and 100% dosages were 3, 9, 125 and 48 hours, respectively.

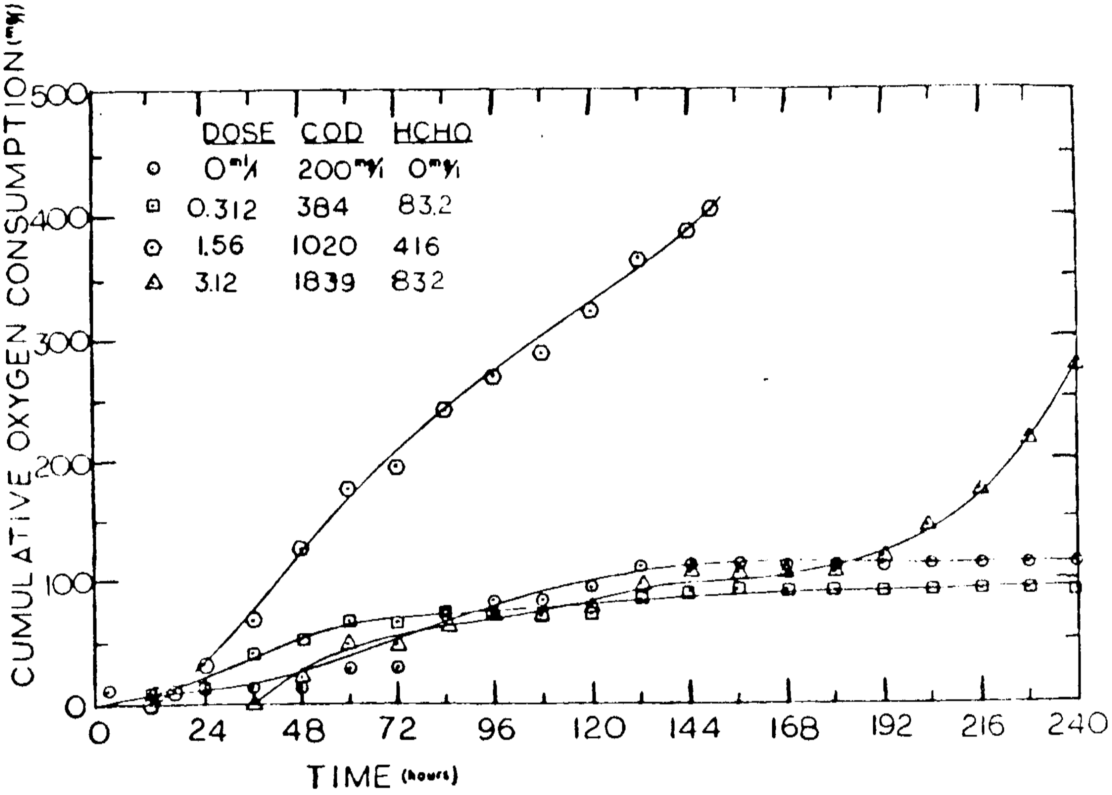


Figure 3-4: Response of aerobic batch cultures to Aquakem (active ingredient: formaldehyde). Dose based upon manufacturer's recommendation of 8 oz. per 10 gallons of waste.

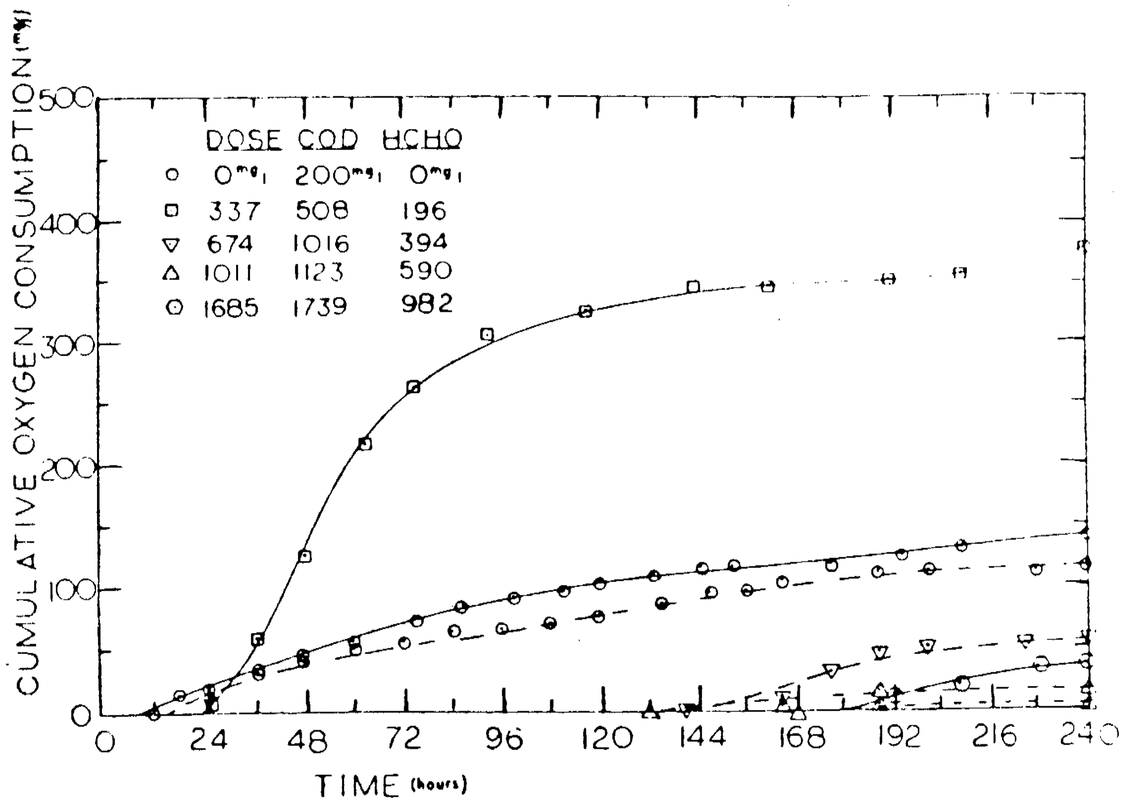


Figure 3-5: Response of aerobic batch cultures to T-5 (active ingredient: Paraformaldehyde). Dose based upon manufacturer's recommendation of one packet (2.25 oz.) per 10 gallons of waste. Solid lines represent data from an assay initiated on Sept. 9, 1981; dashed lines an assay initiated Sept. 22, 1981.

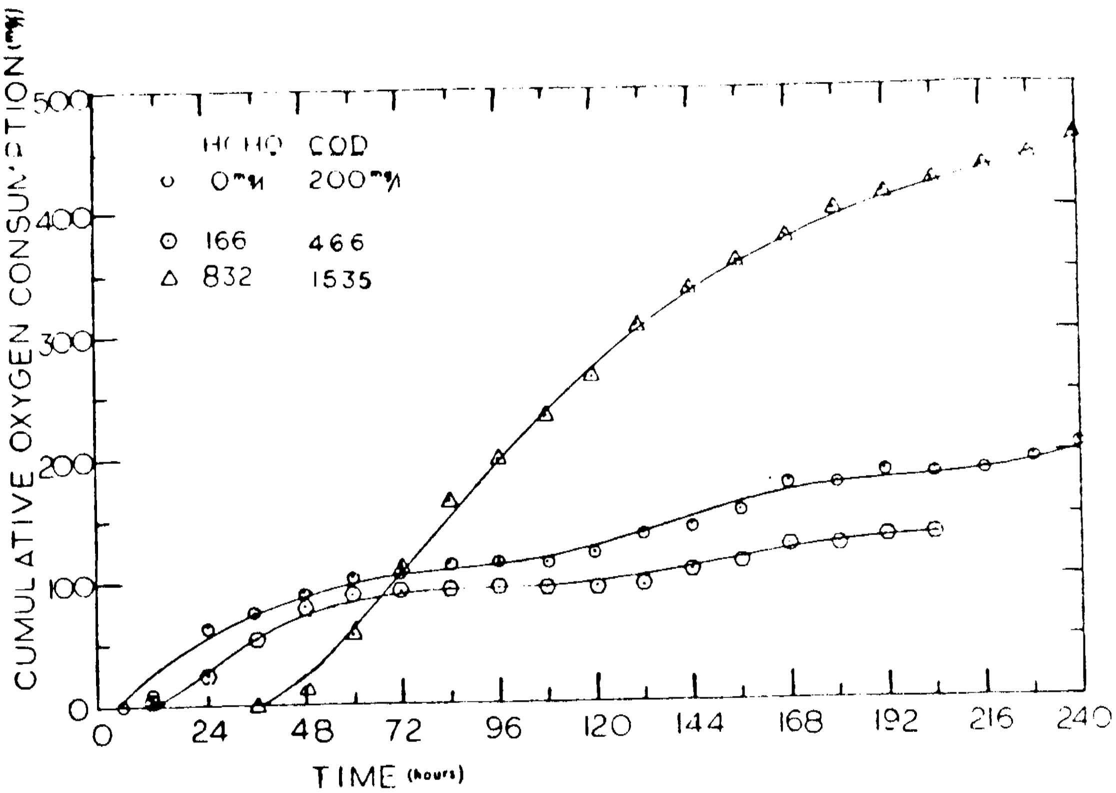


Figure 3-6: Response of aerobic batch cultures to formaldehyde.

In two aerobic assays conducted with T-5 (Figure 3-5) dosages equivalent to 40%, 60% and 100% of the manufacturer's recommendations caused extreme toxic effects with final oxygen consumption less than half that in the control. Oxygen consumption in the reactor exposed to a 20% dose of T-5 exceeded the control by 240 mg $O_2$/L, indicating apparent oxidation of the additive.

In the aerobic assays with reagent grade formaldehyde (Figure 3-6), reactors were spiked with 166 and 832 mg HCHO/L, roughly equivalent to the formaldehyde content of 20% and 100% dosages of Aquakem. Both dosages caused inhibition followed by acclimation. The reactor spiked with 166 mg HCHO/L had a 21 hour lag period and the reactor with 832 mg HCHO/L had a 54 hour lag period compared to a 12 hour lag period in the control.

In an aerobic assay conducted with Wastaway II the response to a dose equivalent to 10% of the manufacturer's recommendation was the same as that in the control. In a test with a 100% dose oxygen consumption did not start until 10 hours after it started in the control. However, acclimation apparently occurred then, and oxygen uptake followed a pattern similar to that of the control (Kiernan, 1982).

The aerobic assays conducted with Trailerzyme (active ingredient: enzymes) showed no toxicity in any test.

Summarizing the aerobic assays, the enzyme-based additive was easily degradable at all concentrations tested, and the oxalate-based additive caused temporary inhibition of aerobic metabolism at 100% of the recommended dose, although acclimation occurred within 20 hours. A 10% dose had no discernable effect. It was not possible to determine whether this latter additive was biodegraded at either concentration.

The liquid formaldehyde-based additive and pure formaldehyde were slightly inhibitory at concentrations greater than those found in RV waste (416 and 832 mg HCHO/L, respectively). Bacterial cultures eventually acclimated to equivalent formaldehyde concentrations of up to 832 mg/L in both these assays.

In the aerobic assays conducted with the paraformaldehyde-based product, concentrations equivalent to 394 and 590 mg HCHO/L showed pronounced toxicity, with no significant acclimation noted. This may be due to the fact that in these assays the additive was a solid. Walker (1964) found that paraformaldehyde may take up to five weeks to dissolve at 18°C. During the assays, formaldehyde was probably being released into the reactors throughout the entire assay. Neely (1963c) found that when a population is exposed to formaldehyde, it first reduces the formaldehyde concentration to below inhibitory levels before growth can occur. In the assays formaldehyde may have been released into solution at a rate equal to or greater than the bacterial removal rate. In all these assays there was some oxygen uptake, and at the 40% dose and one of the 100% doses oxygen uptake appeared to be increasing at the termination of the assay.

The results are consistent with others reported in the literature which indicate that aerobic bacteria can acclimate to concentrations as high as 1750 mg HCHO/L. There was evidence in both assays using liquid formaldehyde that the additive was being oxidized, since the final oxygen consumption at some test concentrations exceeded that in the blank.

### Algal Assay Bottle Test

The toxicity of formaldehyde, paraformaldehyde and oxalate based additives to algae was evaluated with the Algal Assay Bottle Test (AABT). The results of these assays are summarized in Figure 3-7.

Doses of formaldehyde and paraformaldehyde additives in excess of an equivalent concentration of between 2.7 and 4.9 mg HCHO/ caused nearly complete inhibition of algal growth. This is less than 3% of the formaldehyde concentrations found in RV waste.

This may not be as troublesome as it appears since S. capricornutum is not necessarily an important alga in sewage treatment lagoons. The algal species in these lagoons may be more or less susceptible to formaldehyde toxicity than the test alga. The AABT is conducted in a medium with few organic molecules which may react with and remove formaldehyde from solution. Results reported in Table 3-1 indicate that reactions occurring in RV waste can remove significant amounts of formaldehyde from solution. Additionally, in sewage treatment lagoons bacteria will be metabolizing formaldehyde as it is added to the system. Lagoons have extremely long retention times. Bacteria will have ample opportunity to acclimate to formaldehyde. If the rate for formaldehyde input remains below biological and chemical removal rates, its concentration will remain low. The oxalate-based additive had no effect on S. capricornutum growth at doses between 2.8% and 50% of the manufacturer's recommended dose.

No enzyme-base additive was tested, but bacterial bioassays indicate that such compounds can be rapidly and efficiently removed from waste samples.

## SUMMARY AND RECOMMENDATIONS

Toxicity assays were conducted to determine the potential impacts of RV additives on the organisms important in biological waste treatment.

All assays were batch assays; organisms were inoculated into a known media, incubated for a set amount of time and the amount of metabolism by or

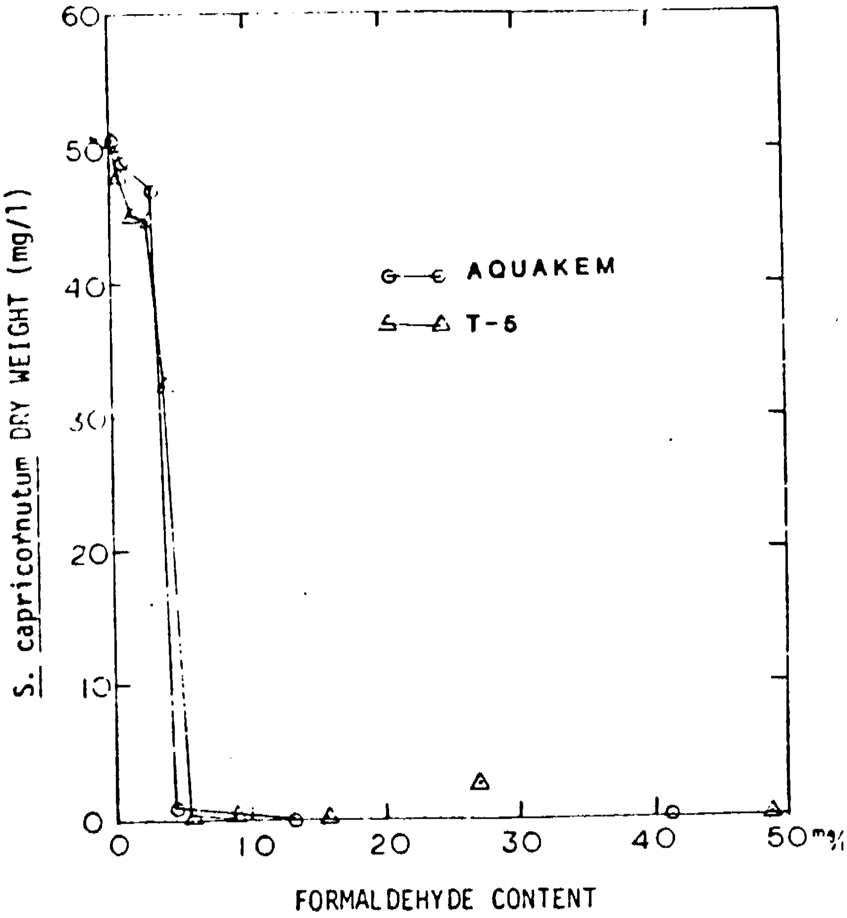


Figure 3-7: Algal assay bottle test data summary for Aquakem and T-5.

growth of the inoculum was measured. If the amount of metabolism or growth in batches exposed to additives was significantly less than that in controls, toxicity was inferred. If metabolism or growth was delayed but still reached the level of the controls, the response was defined as inhibition. In cases where toxicity or inhibition was demonstrated, the results should be interpreted as an indicator of possible problems rather than proof a problem will ocur. Chou, et al. (1978) reported that many compounds which were not acclimated in batch studies were metabolized in continuous flow systems.

Formaldehyde is toxic at concentrations between 100 and 150 mg HCHO/L to mixed unacclimated anaerobic cultures. This is slightly below the average formaldehyde concentration of RV waste of 170 mg/L. This average concentration was calculated assuming that when formaldehyde bearing and non-formaldehyde bearing wastes are mixed the only effect will be dilution. In actual treatment systems, chemical reactions will also occur and the final formaldehyde concentration will probably be lower. This, plus the likelihood that anaerobic organisms can acclimate to formaldehyde, makes it unlikely that RV waste will cause serious problems in anaerobic treatment processes.

A similar conclusion applies for aerobic waste treatment processes. In the aerobic assays, only the paraformaldehyde-based compound caused long-term effects. Acclimation and dilution make it unlikely that a situation would occur in a treatment process where enough paraformaldehyde remains undissolved to provide a long term source of an inhibitory dose of formaldehyde.

Formaldehyde toxicity to algae is a potential problem in lagoon treatment systems. However, since chemical reactions and biological removal will occur in such lagoons, the problem may not arise. Chlorophyll a should be monitored in lagoons receiving RV waste and compared to data collected prior to RV waste inputs. If there is a dramatic or sustained drop in this indicator, algal toxicity may be assumed. If the lagoons become anaerobic, aerators may be required.

When bioassays are used to evaluate the toxicity of a complex product they integrate the effect of all of its components. No attempt was made to determine if the surfactants, dyes or perfumes present in RV tank additives had any toxic effects. Formaldehyde was assayed separately because it is the active ingredient in so many additives and because it can be measured quantitatively in the laboratory with relative ease. The fact that the assays conducted with formaldehyde-based additives compared favorably with assays using pure formaldehyde indicates that formaldehyde probably is responsible for most additive toxicity.

Non-biological removal of formaldehyde from solution can occur through a number of mechanisms, and will probably be enhanced if RV waste is mixed with other organic-rich waste streams. For this reason, it appears advantageous to use combined treatment systems in which RV wastes and other rest areas wastes are treated together, rather than segregating these wastes.

# CHAPTER 4: EFFECTS ON TREATMENT SYSTEMS

## SEPTIC TANK/DRAINFIELD TREATMENT SYSTEM INVESTIGATIONS

The primary function of a septic tank is to provide removal of suspended solids by settling or flotation. Other important functions include biological decomposition of solids and storage of sludge and scum. Settleable solids and partially decomposed sludge settle to the bottom of the tank and accumulate. A scum of low density material, including fats and greases, rises to the top. Clarified liquid flows through an outlet opening below the scum layer. Anaerobic digestion reduces the volume of sludge and scum in the tank as organic material is biologically converted to methane and carbon dioxide.

### Objective

Septic tank contents and drainfield leachate were sampled from systems servicing RV disposal stations to determine the impact of the RV waste on the operability of those systems.

### Procedures

Wastewater was collected from the RV disposal septic tank systems at Wenberg State Park in Snohomish County, Washington, and Dash Point State Park in King County, Washington.

The Wenberg system consists of one disposal station serviced by a three-compartment septic tank with capacities of 3780 liters (100 gal), 2530 liters (670 gal), and 1250 liters (330 gal) respectively. There are 60 meters (200 ft) of drainfield trench with 62 square meters (670 sq ft) of sidewall infiltration area. The soil percolation rate was 4.04 minutes/cm (1.6 in/min). The drainfield was sized for 3400 L/d (900 gal/d). The system was operating well. The Dash Point State Park drainfield had failed about three weeks prior to collecting samples. Odorous septic tank water had surfaced in the drainfield.

Septic tank water samples were collected from the middle of the water column from each tank at Wenberg State Park and from the distribution box at Dash Point State Park. Drainfield water samples at Wenberg were obtained through a lysimeter plate, which was buried in the drainfield soil about 30 cm (1 ft) horizontally away from, and about 15 cm (6 in) below, the bottom of a gravel-filled trench. At Dash Point, a hole about 90 cm (3 ft) deep was dug about 30 cm (1 ft) away from a gravel-filled drainfield trench. Septic tank water was allowed to seep out of the soil and collect in the hole. The water seemed to seep from several spots in the saturated soil.

## RESULTS AND DISCUSSION: ANALYSES OF SEPTIC TANK AND DRAINFIELD WATER

Analytical results for septic tank water samples were given in Table 4-1. Results from the drainfield water samples are given in Table 4-2.

Sludge total solids concentration was 5.3%. Scum total solids concentration was 19.1% and volatile solids concentration was 13.1%.

### RV Septic Tank Effluent Characteristics

Table 4-1 shows that effluent from an RV wastewater septic tank is very strong in total and soluble COD and $BOD_5$, and has high total and volatile suspended solids concentrations.

Using typical RV wastewater and septic tank effluent characteristics, efficiencies for RV septic tanks have been estimated (Table 4-3). Caution should be used in applying these efficiencies since typical characteristics were developed from two separate sources and the typical influent

Table 4-1. Chemical analysis of Water from Septic Tanks Receiving RV Wastewater

|  | Wenberg State Park |  |  |
|---|---|---|---|
| **11-09-80** | **Tank 1** | **Tank 2** | **Tank 3** |
| Scum, cm (ft) | 46 (1.5) | 0 | -- |
| Sludge, cm (ft) | 30 (1.0) | 30 (1.0) | -- |
| Total COD, mg/L | 1620 | -- | -- |
| **4-10-81** |  |  |  |
| Scum, cm (ft) | 38 (1.2) | 0 | -- |
| Sludge, cm (ft) | 20 to 36 (0.7 to 1.2) | 15 (0.5) | -- |
| Total COD, mg/L | 5360 | 2500 | -- |
| Soluble COD, mg/L | 3290 | 1850 | -- |
| TSS, mg/L | 700 | 80 | -- |
| VSS, mg/L | 550 | 70 | -- |
| Temperature, °C | 12 | 12 | -- |
| pH | 6.9 | 7.05 | -- |
| Formaldehyde, mg/L | 5 | 5 | -- |
| **8-20-81** |  |  |  |
| Scum, cm (ft) | 58 (1.9) | 0 | 0 |
| Sludge, cm (ft) | 30 (1.0 | 25 (0.8) | 18 (0.6) |
| Total COD, mg/L | 3180 | 2870 | 2870 |
| Soluble COD, mg/L | 1900 | 1980 | 1820 |
| $BOD_5$, mg/L | 1780 | 1490 | 1430 |
| TSS, mg/L | 460 | 170 | 170 |
| VSS, mg/L | 410 | 140 | 150 |
| Formaldehyde, mg/L | 5.5 | 6.8 | 8.7 |

| **9-9-81** | **Dash Point State Park Distribution Box** |
|---|---|
| Total COD, mg/L | 2310 |
| $BOD_5$, mg/L | 1360 |
| TSS, mg/L | 300 |
| VSS, mg/L | 240 |
| Formaldehyde, mg/L | 9.2 |

Table 4-2. Chemical Analysis of Drainfield Water from Septic Tanks Receiving RV Wastewater

| | Dash Point<br>9-9-81 | Wenberg<br>9-14-81 |
|---|---|---|
| Total COD, mg/L | 1880 | 1240 |
| Soluble COD, mg/L | -- | 870 |
| BOD5, mg/L | 910 | 460 |
| Formaldehyde, mg/L | 6.0 | 4.8 |

characteristics are not necessarily representative of the influent to the tanks from which the effluent sample results were obtained.

Formaldehyde levels in both RV septic tank water and drainfield water were about 5 to 10 mg/L. This is both a surprising and encouraging result. If there were no mechanism for formaldehyde removal in the tank, one would expect to see a concentration of 170 mg/L, which is the average concentration found in RV holding tank water. If there was biological degradation of formaldehyde, degradation should continue until less than 5 mg/L formaldehyde remains, particularly during the off-season months when detention time in RV septic tanks is long. It is interesting to note that the lowest formaldehyde levels achieved in Pearson's study were 4.0 and 5.8 mg/L. Formaldehyde can be removed from septic tank systems by nonbiological mechanisms as well as by biodegradation. It appears that, for reasons not well understood at this time, formaldehyde removal ceases in anaerobic systems when formaldehyde concentration drops to about 5 mg/L. Regardless of the exact removal mechanism it is clear that the formaldehyde levels in the septic tank were not high enough to eliminate anaerobic biological activity.

Table 4-3. Removal Efficiency of Septic Tanks for Various Constituents in RV Wastewater

| Pollutant Characteristic | RV Wastewater Influent | RV Wastewater Effluent | % Removal |
|---|---|---|---|
| COD, mg/L | 8320 | 2870 | 65% |
| $BOD_5$, mg/L | 3110 | 1430<br>828 | 54%<br>73% |
| TSS, mg/L | 3120 | 170<br>756 | 95%<br>76% |
| VSS, mg/L | 2640 | 150 | 94% |
| HCHO, mg/L | 170 | 10 | 96% |

## Septic Tank Design Practices

### Design Guidelines Based on Hydraulics

Several design manuals provide guidelines for designing septic tanks. Generally, septic tanks are sized to provide adequate detention time for solids removal based on experience.

The Washington Highway Hydraulic Manual (1972) simply requires a 24-hour minimum detention time:

$$V = Q$$

where V = septic tank volume, liters (gal)

Q = design flow rate, liters/d (gal/d)

The Washington State Department of Transportation no longer uses this design equation. Instead, criteria from the Washington State Department of Social and Health Services, which are very similar to those described by Otis, et al., (1980), are used (McIntosh, 1982).

Otis et al. (1980), state that a 24-hour liquid detention time is required at maximum sludge depth and scum accumulation. For flows between 2800 and 5700 liters per day (740 and 1,500 gal/d), the tank may be sized for a 36-hour detention time. This allows 33 percent of the tank volume to be used for sludge and scum storage. For flows between 5,700 and 57,000 L/d (1,500 and 15,000 gal/d) Hughes' equation may be used.

Hughes et al. (1977) give the following equation for septic tank design at highway rest areas:

$$V = 4250 + 0.75\ Q$$

where V = septic tank volume, liters (or gal. depending on the units used for Q), 5700 liters (1,500 gal) minimum

Q = design flow rate, liters (or gal) per day.

Pearson et al. (1980) used the correlations from Hughes et al. (1979) to develop nomographs for septic tank sizing. These correlations specify a 36-hour minimum detention time:

$$V = 1.5\ Q$$

Figure 4-1 shows septic tank size as a function of designed flow rate for each of these design correlations. Figure 4-2 shows these correlations using detention time as a function of daily flow.

Each of these septic tank sizing equations is based on providing hydraulic detention time for settling of solids. None addresses sludge and scum accumulation or designed service intervals between pumpout. Common practice is to pump domestic waste septic tanks every three to five years without measuring sludge or scum accumulation (Otis et al., 1980; Seabloom, 1981).

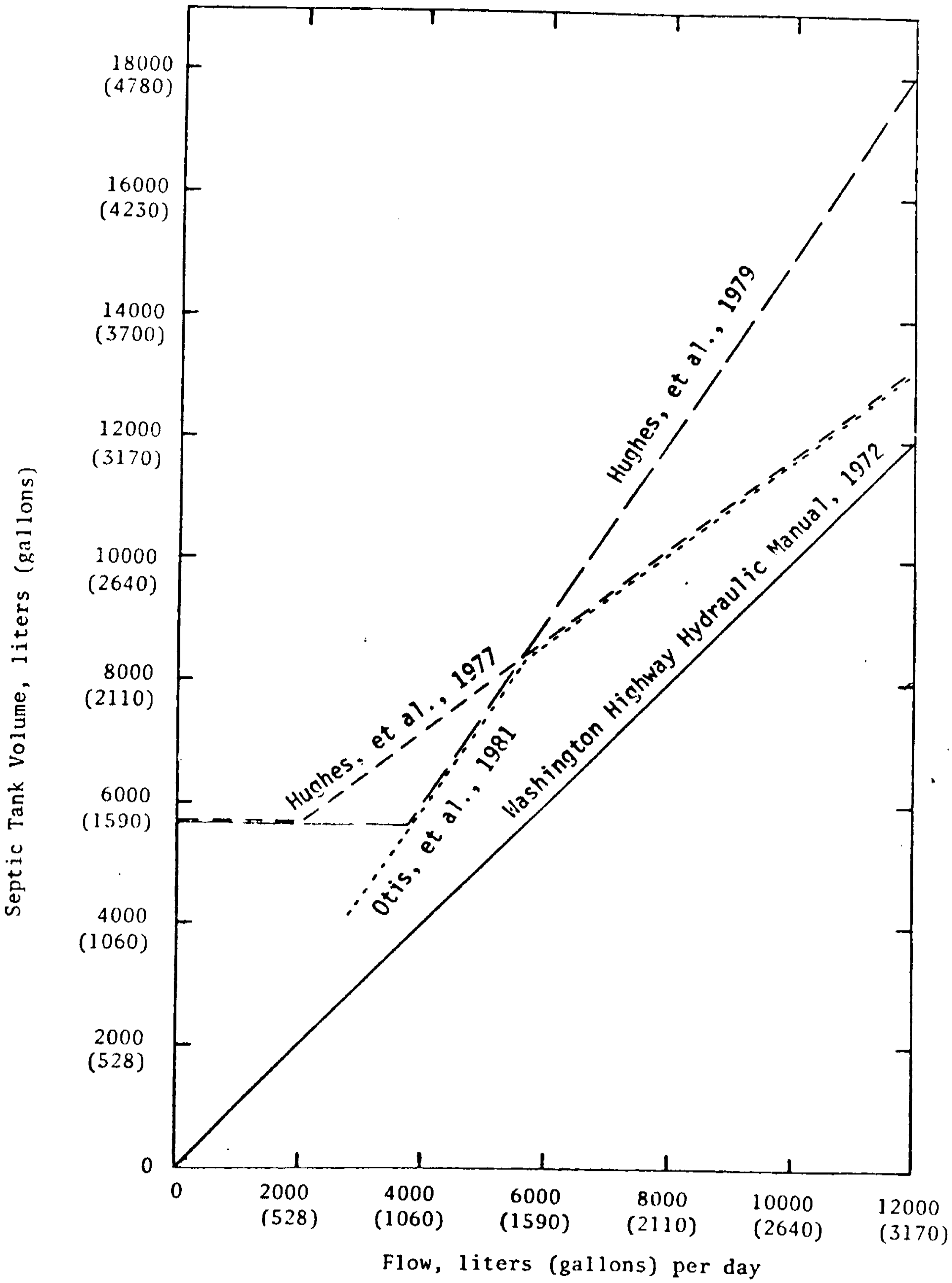


Figure 4-1: Comparison of septic tank sizing criteria recommended by several authors.

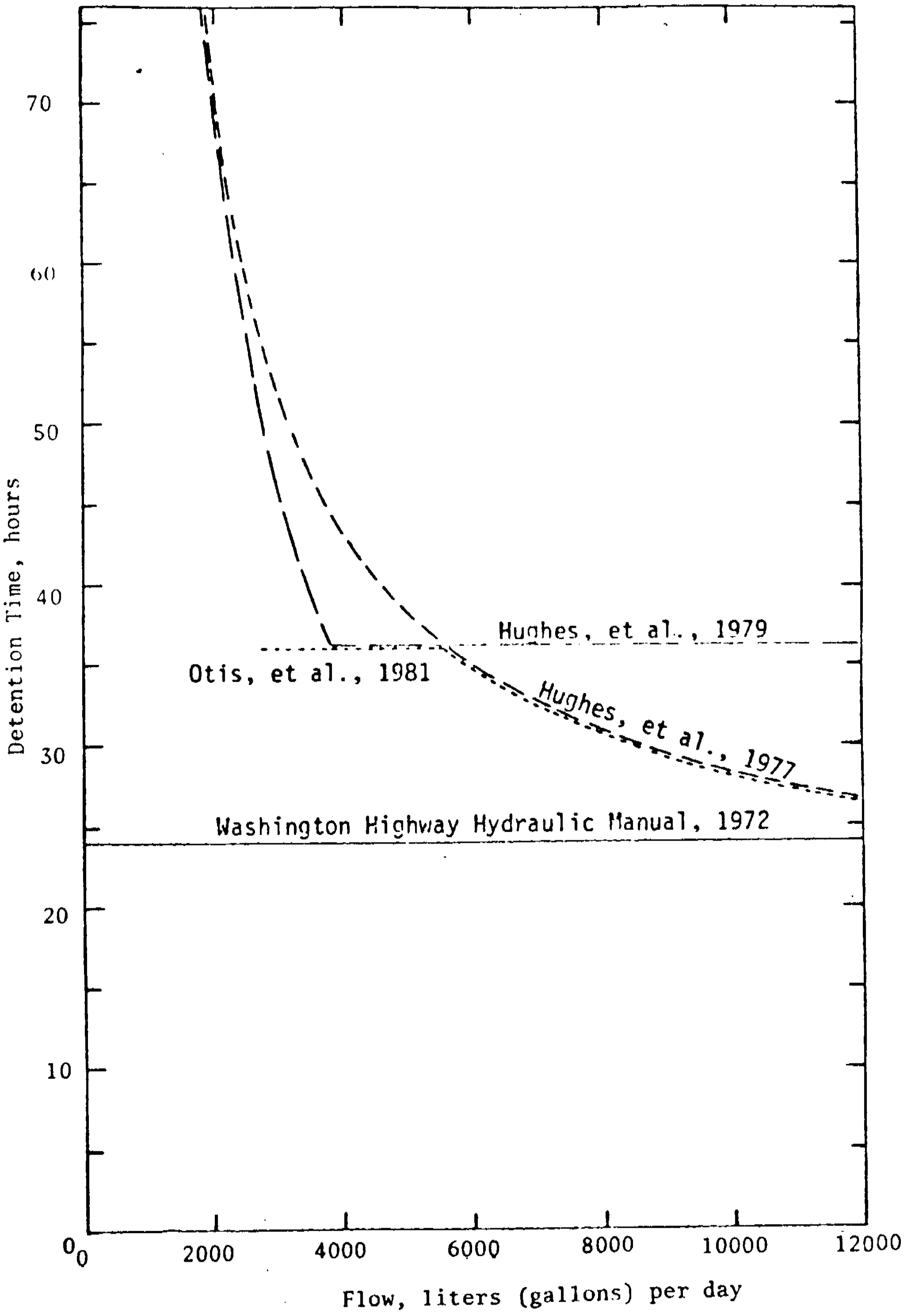


Figure 4-2: Septic tank detention time criteria.

Since RV wastewater contains very high concentrations of suspended solids, solids accumulation in RV waste septic tanks will be substantially greater than in domestic waste septic tanks treating the same volume of wastewater. Therefore, sludge and scum accumulation and pumpout interval should be considered in addition to hydraulic residence time when sizing septic tanks for RV waste. Septic tanks used at rest areas should be sized for at least one year's sludge and scum accumulation and should always have at least two compartments.

### Sludge and Scum Accumulation

As sludge and scum accumulate in a septic tank, the effective liquid volume and detention time decrease. With large accumulations, sludge scouring increases, treatment efficiency decreases, and suspended solids pass through the tank. One cause of clogged drainfields is failure to pump out the septic tank when it is needed.

Actual measurement of sludge and scum accumulation is the only way to determine when a tank needs to be pumped.

We have developed a design equation which we believe is acceptable for preliminary design of septic tanks receiving high-strength wastes. The equation is based on a model which accounts for the fact that some of the solids entering a septic tank are degradable, while others are not. The model also takes into account the possibility that the degradation rate in septic tanks receiving RV wastes may be slower than in those receiving domestic wastes due to the inhibitory effects of formaldehyde. While we feel this model is acceptable, it must be emphasized that some of the parameters had to be evaluated based on a study conducted more than 30 years ago when sampling techniques and the composition of domestic waste may have been different from the present. Therefore, frequent monitoring of sludge and scum levels in septic tanks receiving RV waste is strongly recommended.

The complete model derivation is provided in a thesis by Brown (1982). The resulting equation for the volume of sludge and scum accumulation is:

$$V(t) = r_i t - \frac{ar_i t}{b} + \frac{ar_i}{b^2} \ln (1 + bt)$$

Where $V(t)$ = volume of sludge and scum at time t, liters or gal

$r_i$ = volumetric rate of sludge and scum input, liters/yr or gal/yr

$t$ = service time since last pumpout, years

$a,b$ = constants characteristic of the biodegradability of the sludge and scum

This equation has been used in conjunction with data from Wiebul et al (1949) to evaluate a, b, and $r_i$ for domestic septage. The resulting equation is:

$$V(t) \text{ (liters)} = 2.65\,t + 34.2 \ln (1 + 2.47\,t)$$

$$V(t) \text{ (gal)} = 0.70\,t + 9.0 \ln (1 + 2.47\,t)$$

This model is plotted with Weibul's data in Figure 4-3. After a few years the accumulation rate is practically constant with time. This indicates that, after a year or two, accumulation of removable solids is a small term in the mass balance compared to the accumulation of non-removable solids.

This model for septic tank accumulation can be applied to RV wastewater by adjusting the constants a, b, and $r_i$.

Assuming that as is the case for domestic septage, the average solids concentration in accumulated RV sludge and scum is 12%, and approximately 3/4 of the input solids are ultimately degradable:

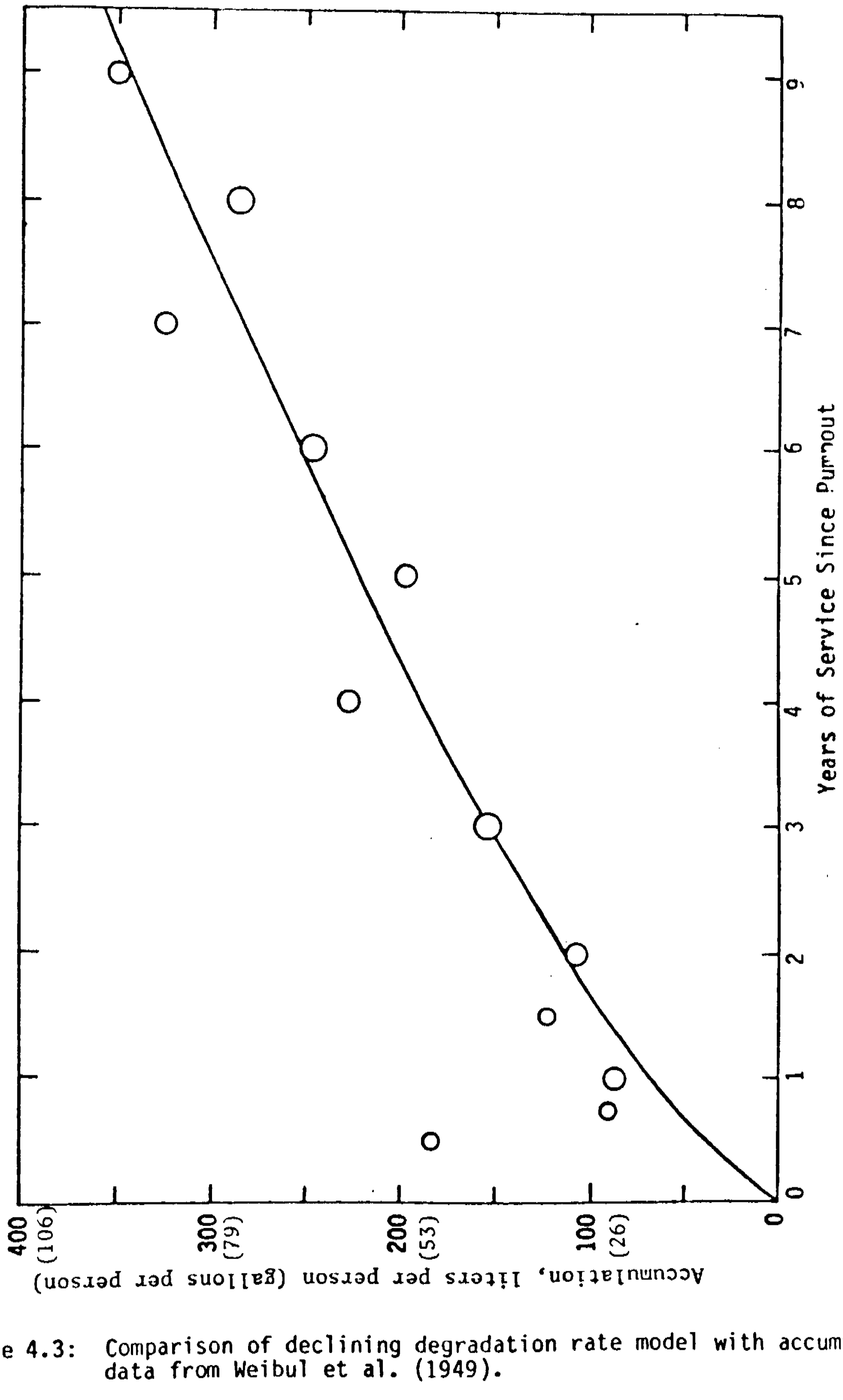


Figure 4.3: Comparison of declining degradation rate model with accumulation data from Weibul et al. (1949).

$$V_{t,RV} \text{ (liters)} = 140t + \frac{448}{b} \ln(1 + bt)$$

$$V_{t,RV} \text{ (gal)} = 37t + \frac{118}{b} \ln (1\ 0\ bt)$$

where $V_{t,RV}$ = accumulation

$t$ = time since last pump-out, years

$$b = 2.47 \times (1 - \frac{\%\text{ of inhibition}}{100})$$

The effect that various degrees of inhibition of the initial degradation rate would have on sludge and scum accumulation is shown in Figure 4-4. Fifty percent inhibition means that the maximum rate of sludge degradation for RV waste is one half that for domestic waste.

Figure 4-4 shows the sludge and scum accumulation in an RV waste septic tank based on this model. The curves are based on one RV input per day. To adjust to any other basis, the accumulation is multiplied by the desired daily RV input rate.

Kiernan (1982) studied formaldehyde inhibition on total gas production in acclimated batch anaerobic toxicity studies. Although his tests were not designed to give kinetic information, the gas production rates during the growth phases may be used to obtain very rough estimates of inhibitory effects on degradation rate. For formaldehyde concentrations of 0, 40, 80, 160 and 240 mg/L, gas production rates during the growth phases were 2.5, 2.0, 1.1, 0.7, and 0.5 mL/d, respectively. This corresponds to 0%, 20%, 57%, 74%, and 80% inhibition in gas production rate for the respective formaldehyde concentrations. Raw RV waste contains 170 mg/L formaldehyde, and the concentration in a properly operating septic tank would be significantly less.

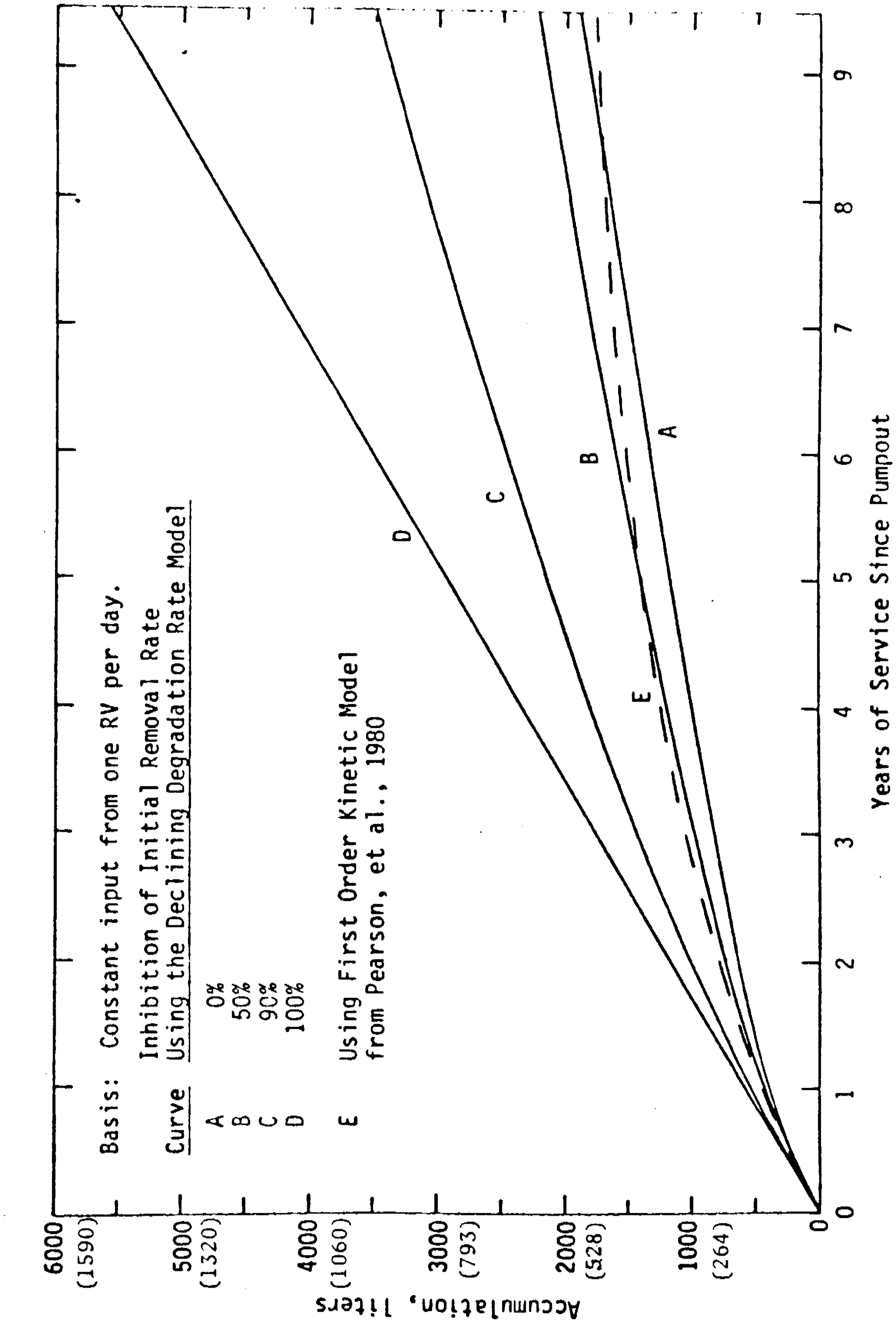


Figure 4-4: RV wastewater septic tank sludge and scum accumulation.

## Recommendation for Sizing RV Waste Septic Tanks

Septic tanks for RV wastewater should be sized with consideration for both hydraulic detention time and solids accumulation. Since RV waste is very concentrated, there will be much more sludge and scum accumulated for a given quantity of water than in domestic tanks. The relationships used for domestic septic tank sizing are based only on hydraulic detention time and do not address accumulation or pumpout interval.

Otis, et al., (1980) recommended that hydraulic detention time be 24 hours at the maximum sludge and scum accumulation. A conservative design should provide this detention time at the maximum daily flow rate. Thus, a septic tank for RV wastewater can be sized by adding the volume required for a minimum 24-hour detention time ($V_h$) to the volume required for sludge and scum ($V_s$) at the designed service life prior to pumpout. A second conservative assumption is that there is 90% inhibition, i.e. 90% reduction of the degradation rate. The resulting septic tank sizing equation is given by adding the volume required for hydraulic detention to that required for solids:

$$V = V_h + V_s$$

$$V\ (\text{liters}) = Q_{max}\ (\text{liters/d}) + \frac{n}{365}\,[140\,t + 1812\ \ln\,(1 + 0.25\,t)]$$

$$V\ (\text{gal}) = Q_{max}\ (\text{gal/d}) + n\,[37t + 480\ \ln\,(1 + 0.25\,t)]$$

where V = Septic tank size

$V_h$ = Volume required to maintain minimum acceptable hydraulic detention time

$V_s$ = Volume occupied by sludge and scum

$Q_{max}$ = Designed peak flow rate for system

n = Designed average number of RVs per year

t = Designed service interval between pumpout, years

$Q_{max}$ is estimated to be three times the design loading basis development in Chapter 2. The ratio of maximum day to average day for the July-August period is 2.9 for the Sea Tac Regional Station. Other areas are expected to be similar.

Sludge and scum accumulation will depend on loadings over long cycle times since biodegradation is relatively slow and pumpouts are infrequent. The design relationship is plotted in Figure 4-5 for average use rates of 1000, 5000, and 10,000 RVs per year and a maximum daily wastewater flow rate of 6200 L (1640 gal), equivalent to the waste from 100 RVs. The design loading for the July/August period, is estimated be when converted into RV's per month, can be multiplied by six to obtain the estimated annual use of disposal station in Washington. This factor is known only very roughly since traffic data were not obtained in the late autumn, winter or early spring. However, the factor is approximately correct and provides a basis for septic tank sizing for sludge and scum accumulation. In all cases frequent and regular measurements of sludge and scum should be made to determine when pumpout is needed.

Figure 4-5 demonstrates the importance of considering sludge and scum accumulation when sizing RV septic tanks. At 1000 vehicles per year, the hydraulic flow rate term dominates. However, at 5000 RVs per year, the accumulation term becomes increasingly important for more than one year of service time, and at 10,000 RVs per year, the accumulation term dominates after one year of service time.

## Drainfield Design

Where soil conditions are suitable, subsurface soil absorption is a simple, effective method of treating septic tank effluent. Partially treated

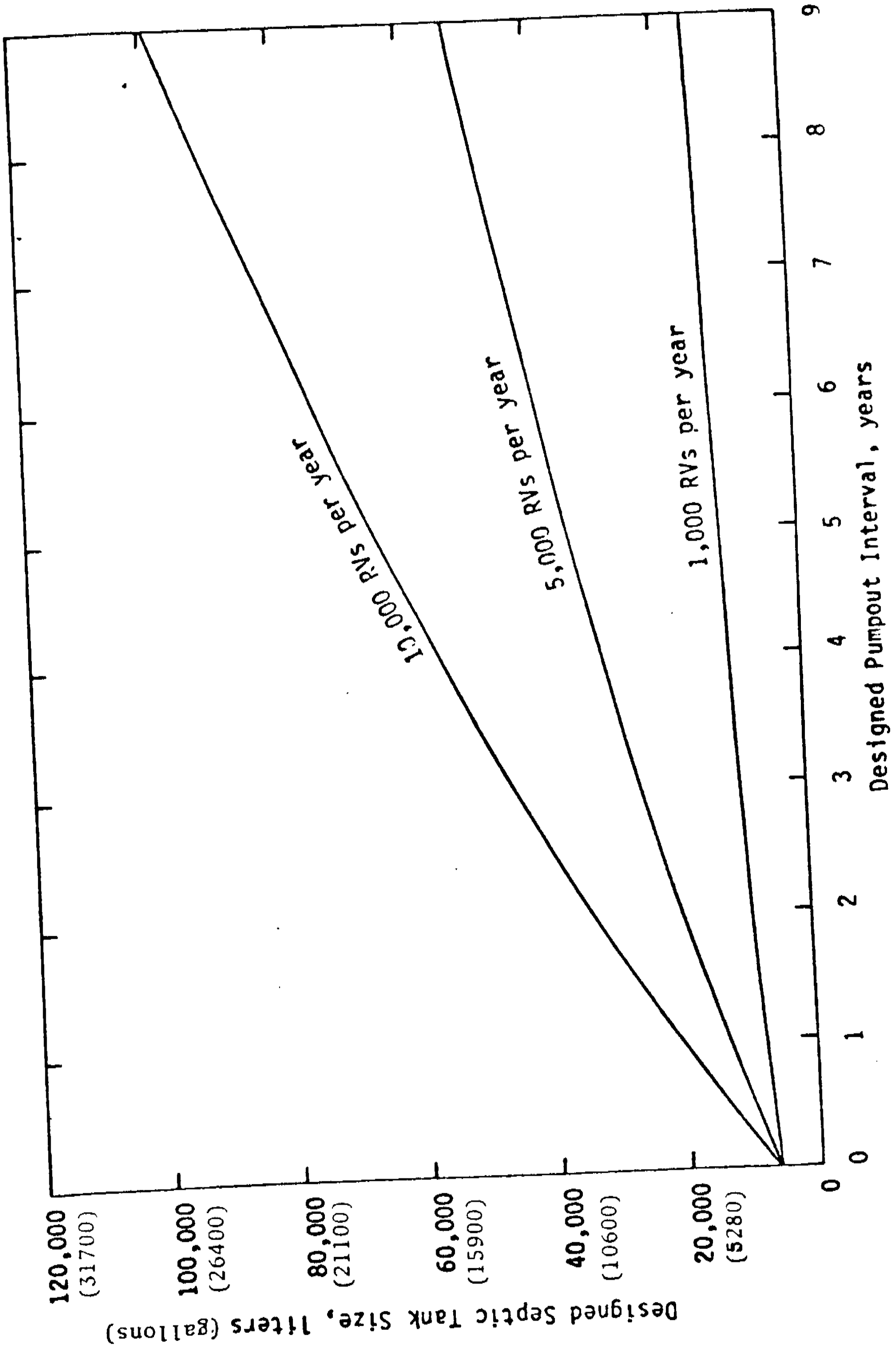


Figure 4-5: Septic tank design volume for RV disposal stations.

wastewater is discharged below the ground surface where it is absorbed and treated as it percolates through the soil. Travel through 0.6 to 1.2 meters of unsaturated soil is necessary to provide adequate removal of pathogens and pollutants from domestic septic tank effluent before reaching the groundwater (Bouma, 1975; Otis, 1980).

Several different designs of subsurface soil absorption systems may be used including trenches, beds, seepage pits, mounds, fills, and artifically drained systems. All of these systems are covered excavations filled with porous media with a means for introducing and distributing the wastewater throughout the system. The following discussion concentrates on the trench drainfield system, since it is the most commonly used soil absorption system (Otis, 1980).

### Drainfield Clogging

Continuous application of wastewater causes a clogging mat to form at the soil infiltrative surface. This mat slows the movement of water into the soil. This can be beneficial, because it helps to maintain unsaturated soil conditions below the mat. Fortunately, the mat seldom seals the soil completely. The size of a drainfield must be based on the infiltration rate through the clogging mat that ultimately forms. Formation of the clogging mat depends primarily on loading pattern and soil conditions, although other factors may be important (Otis, 1980).

The clogging process is related to the rate of biological growth and therefore to the food and solids load. One might assume a linear relationship between increased BOD and solids loading and increased clogging. However, studies have shown only small differences in clogging rate over a range of wastewater qualities.

Laak (1976) gives the following relationship, which he develped in his doctoral thesis (1966), to adjust required drainfield area to loading:

$$\text{Adjusted Area Required} = \text{Area Required for Standard Septic Tank Pretreatment} \times \frac{(BOD_5 + TSS)^{\frac{1}{3}}}{250}$$

where $BOD_5$ and TSS are expressed in mg/L, and 250 mg/L is the sum of $BOD_5$ plus TSS for standard septic tank effluent. He points out that this relationship is valid only for domestic sewage and does not apply to soils with low permeability. The wastewater carrying capacity of soils with low permeability may be governed by the hydraulic capacity of the soil rather than that of the clogging mat.

Drainfield Sizing Practices

The Manual of Septic Tank Practice (1969), Washington's Highway Hydraulic Manual (1972), and Hughes, et al., (1977) all use the following correlation for drainfield sizing:

$$Q = \frac{5}{t^{0.5}}$$

where Q = Rate of sewage application, gal/d-ft$^2$

t = Percolation rate, min/in

This simple correlation was developed empirically by Henry Ryon for New York State in the late 1920's. Winneberger (1976) and McGauhey (1975) have criticized the overuse and the overextension of this correlation. Ryon had measured percolation rates and plotted curves relating loading and percolation rates.

The use of the percolation test data for soil absorption system design is based on the assumption that the ability of a soil to absorb sewage effluent over a prolonged period of time may be predicted by the soil's initial ability to absorb clean water. However, the soil beneath properly designed and operating systems should be unsaturated, because the clogging mat restricts flow at the infiltrative surface. Therefore, the percolation test under saturated conditions does not properly describe the movement of drainfield moisture.

Bouma (1975) measured unsaturated hydraulic conductivity in various soil types. This procedure offers a direct measurement of hydraulic conductivity, but it is time consuming and requires a skilled operator. However, different soils within the same textural groups have similar conductivities. Therefore, by defining families of curves for groups of soils, the hydraulic conductivity characteristics of a particular soil or site can often be predicted without on-site testing (USEPA, 1978). Based on Bouma's work and on observations that maximum acceptable loadings can be correlated with soil texture, Otis, et al., (1980) suggested guidelines for drainfield sizing given in Table 4-4. The Washington State Department of Transportation uses criteria from the Washington State Department of Social and Health Services, which are very similar to those given by Otis, et al., for sizing drainfields (McIntosh, 1982).

## Sizing Drainfields for Servicing RVs

RV septic tank effluent is very strong in COD and BOD, has high suspended solids concentrations, and contains 5 to 10 mg/L formaldehyde. Due to the high strength of this effluent, it is possible that a drainfield that size is based on application rates suggested by Otis will fail prematurely. Some

Table 4-4. Wastewater Application Rates for Domestic Drainfields (1) (from Otis et al., 1980).

| Soil Texture | Percolation Rate min/cm (min/in) | | Application Rate (2) L/d-$m^2$ (gal/d-$ft^2$) |
|---|---|---|---|
| Gravel, coarse sand | < 2.5 | (< 6.3) | not suitable(3) |
| Course to medium sand | 2.5- 13 | (6.3-33) | 49 (1.2) |
| Fine sand, loamy sand | 14 - 39 | (36 -99) | 33 (0.81) |
| Sandy loam, loam | 40 - 77 | (101-196) | 24 (0.59) |
| Loam, porous silt loam | 78 -153 | (198-389) | 18 (0.44) |
| Silty clay loam, clay loam (4) | 154 -305 | (391-775) | 8 (5) (0.20) |

(1) May be suitable estimates for sidewall infiltration rates.

(2) Rates based on septic tank effluent from a domestic waste source. A factor of safety may be desirable for wastes of significantly different character.

(3) Soils with percolation rates < 2.5 min/$cm^{-1}$ can be used if the soil is replaced with a suitably thick (> 0.6 m; > 2 ft) layer of loamy sand or sand.

(4) Soils without expandable clays.

(5) These soils may be easily damaged during construction.

sizing factor should be applied to drainfields receiving this high strength effluent.

A linear relationship for increasing drainfield area with increasing wastewater strength would provide a constant nutrient loading per square meter of drainfield, but this approach is too restrictive. For RV septic tank effluent, which has a total $BOD_5$ and TSS concentration 8.6 times stronger than typical domestic septic tank effluent, a linear relationship would require a sizing factor of 8.6. While such a sizing factor would provide the same mass of nutrients per square meter of drainfield clogging mat, and hence a similar clogging mat density as found in domestic system drainfields, the hydraulic loading for an RV system would only be 12% of the loading which could be transmitted through such a clogging lmat. Also, the work of Laak (1966) and of Daniel and Bouma (1974) does not support a linear relationship between drainfield required area and wastewater strength. Therefore, an appropriate drainfield sizing factor lies somewhere between 1.0 and 8.6.

Although it is a gross overextension of the correlation, the equation presented by Laak might be used to give some indication of an appropriate sizing factor for RV septic effluent. Using the $BOD_5$ and TSS values given in Table 4-3, for effluent from septic tanks receiving RV wastes, the sizing factor becomes:

$$\text{Sizing factor} = \left(\frac{1430 + 170}{250}\right)^{\frac{1}{3}}$$

$$\text{Sizing Factor} = 1.9$$

Therefore, for lack of a better correlation at this time, it is recommended that drainfields for RV septic tank effluent be twice the recommended size for domestic septic tank effluent. This subject should receive further attention.

Combined Restroom and RV Wastewater Systems

RV wastewater at highway rest areas may be diluted with restroom wastewater in a combined septic tank-drainfield system. This would have the beneficial effect of reducing formaldehyde concentration and minimizing inhibition of anaerobic digestion in the tank. However, a combined septic tank system would have a concentrated effluent which would increase drainfield area requirements compared to a system receiving the same flow of weaker rest area wastewater. Sample calculations using the proposed design equation for a rest area servicing 10,000 vehicles per year of which 10% are RVs, and using a five year design pumpout frequency are given by Brown (1982). They indicate that a combined treatment system would require only about half as much septic tank volume (3600 L; 950 gal) as the total septic tank volume required for separate treatment systems (6400 L; 1690 gal). The difference between the two is probably somewhat exaggerated in these calculations because a very conservative estimate was made for the inhibitory effect of formaldehyde on degradation of the unmixed RV waste (90% inhibition).

The decision between combined and segregated RV waste and restroom waste systems should be based on economic considerations including construction cost differences, increased sludge pumping costs for segregated systems, and increased land and materials costs for combined system drainfields. In most cases, combined systems would be recommended since construction costs are likely to be greater for installing two separate systems, the sludge pumping costs are likely to be significant, and the land cost differences are likely to be minor. The only factor which weighs against combined systems is that RV dump stations are much more susceptible to illegal dumping of hazardous or toxic compounds than are other parts of the rest area. If a toxic compound were dumped into the dump station septic system, it would be advantageous to avoid toxifying the restroom treatment system simultaneously. The importance of this factor is impossible to assess at this time, but it should be considered in the overall design strategy.

## EVAPORATIVE LAGOONS

Wastewater stabilization lagoons are relatively shallow basins which retain wastewater for relatively long periods of time. Stabilization in lagoons is attributed to both aerobic and anaerobic bacterial activity.

Upper layers of a lagoon may be aerobic due to photosynthetic oxygen production by algae. Lower regions may be anaerobic due to bacterial uptake of oxygen. The depth of the aerobic and anaerobic zones varies with time of day, available light, mixing, weather, turbidity, and other factors. Algae in a lagoon keep pH high during daylight hours as dissolved $CO_2$, an acid, is used as a carbon source for new cellular material. The pH drops during the night.

Hydrogen sulfide is a product of anaerobic bacterial processes. It is rapidly oxidized to elemental sulfur, sulfates, and other oxysulfur compounds in the presence of oxygen in the aerobic zone. Hydrogen sulfide and other odorous gases produced by anaerobic digestion may evolve from the lagoon if oxygen is absent and pH is low.

Seasonal changes also affect a lagoon. Blooms of various algal species may come and go throughout the year. In colder climates, deep lagoons may experience spring and fall turnovers which may bring septic, odorous compounds from the bottom to the top of the lagoon. During the winter, ice and snow can block available light, and water under the ice may become entirely anaerobic until the spring thaw.

## Lagoon Design Practices

Local evaporation and precipitation data are necessary for determining the required surface area of evaporative lagoons since the wastewater flow rate must not exceed the difference between evaporation and precipitation rates.

The Washington Highway Hydraulic Manual has a further criterion that pond loading be less than 40 pounds $BOD_5$ per acre per day (4.5 $g/m^2$-d). Otis et al., state that while some sources recommend restricting loading to 11 to 35 pounds BOD per acre per day (1.2 to 3.9 $g/m^2$-d) for odor control, supporting data are not available. Most design criteria give loadings of 15 to 50 pounds BOD per acre per day (1.7 to 5.6 $g/m^2$-d) for facultative lagoons. The development of this criteria is based primarily on experience (Middlebrooks et al., 1978).

Lagoons are often lined with about 15 cm of clay or with a synthetic membrane liner to prevent water seepage into groundwater.

## Lagoon Monitoring

### Objective

A totally evaporative, plastic-lined lagoon is used for wastewater disposal at the Selah Creek Rest Area on Westbound Interstate 82 about 25 kilometers north of Yakima, Washington. In mid-summer 1981, an RV disposal station was completed at the rest area, and RV wastewater was directed to the lagoon. Lagoon water characteristics have been monitored since July, 1980, to detect any impact on the lagoon from the RV disposal station.

The RV disposal station was opened at the rest area in early July, 1981. it was closed in mid-November, 1981, and remained closed due to freezing problems until April, 1982.

During the course of this study samples were collected from the lagoon at regular intervals and analyzed for several water quality parameters. Details of the sampling and analytical procedures have been provided by Brown (1982).

## Results and Discussion

Results of the lagoon monitoring are presented in Figures 4-6 through 4-12. None of the water quality parameters changed in an unusual or unexplainable way when RV waste was added to the lagoon influent.

It is doubtful that formaldehyde in the RV waste had any effect on the lagoon. Kiernan (1982) found that algal cultures of *Selenastrum capricornutum* had a toxic threshhold to formaldehyde of about 5 mg/L. At 170 mg/L formaldehyde and 62 1 (16 gal) per vehicle and assuming 50 RVs per week, it would take four months to accumulate that much formaldehyde in the Selah lagoon. Meanwhile, formaldehyde would be removed by biological degradation, physical and/or chemical action and volatilization. Formaldehyde concentration in September, 1981 was less than 1 mg/L. Dissolved oxygen and chlorophyll *a* concentrations at the surface from algal photosynthesis were maintained. Therefore, the algae were not disrupted. As discussed previously, aerobic bacteria were inhibited by formaldehyde at concentrations in the range of 20 to 50 mg/L. Therefore, bacterial action in the lagoon would not have been disrupted either.

It is probable that organic loading from RV waste contributed significantly to the COD and BOD loading in the lagoon. One RV tank contributes approximately 193 g (0.42 lb) $BOD_5$, which is equivalent to the $BOD_5$ loading from 56 vehicles stopping at a rest area.

For the estimated typical traffic pattern, RV waste from 7 RVs per day contributes 1350 g (3.0 lb) $BOD_5$ per weekday while restroom waste from 370

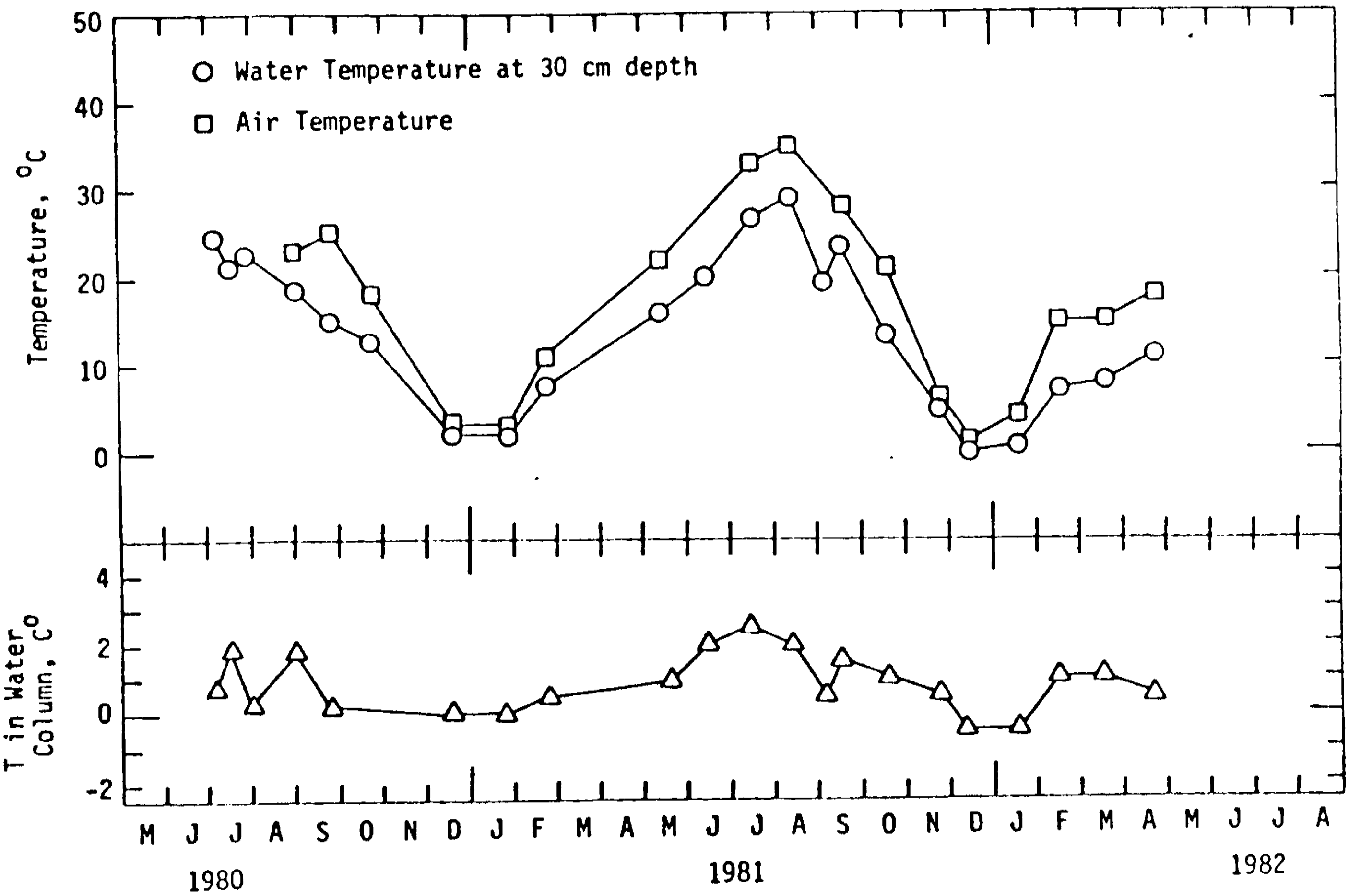


Figure 4-6: Seasonal temperature variations at Selah Creek Lagoon.

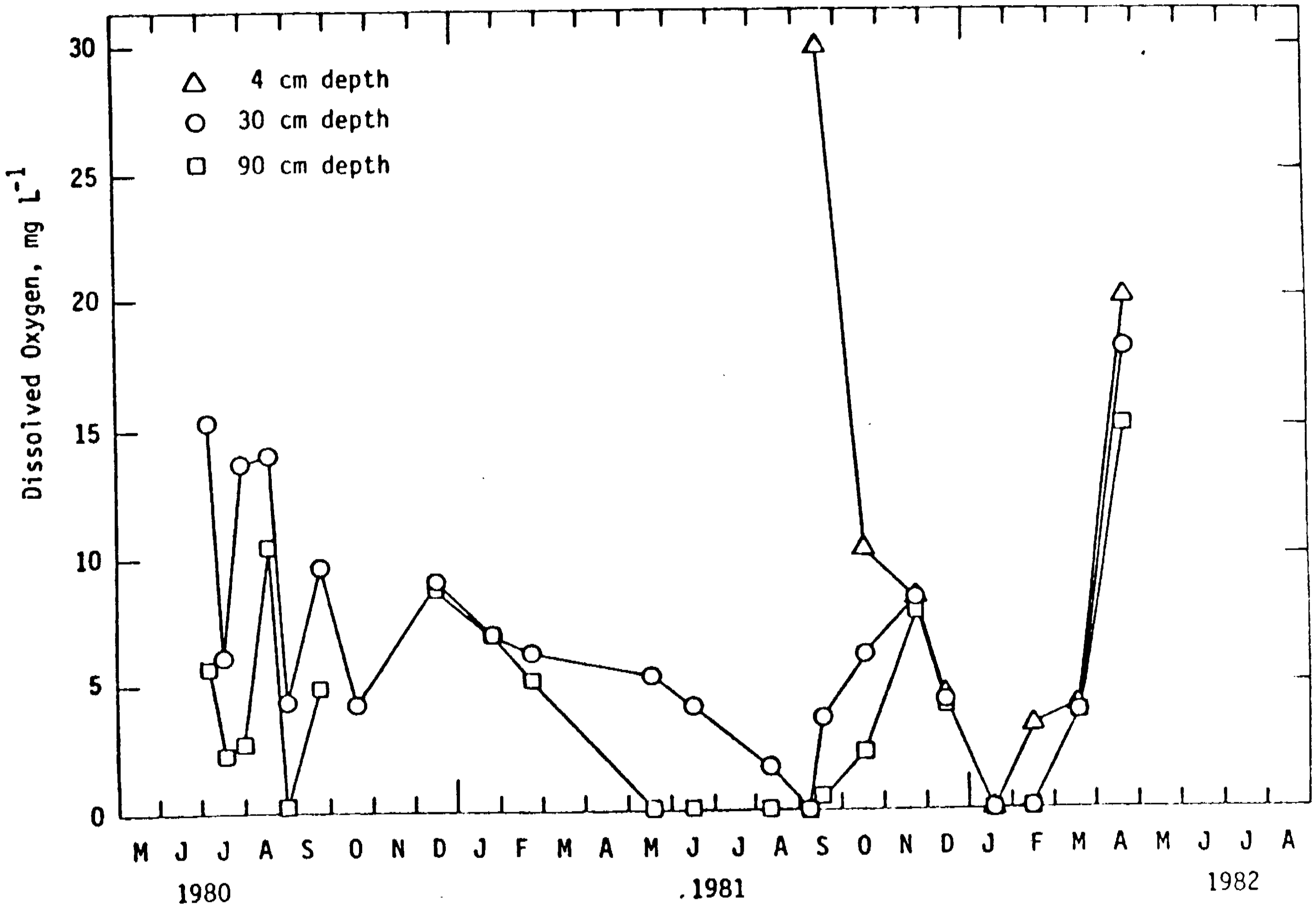


Figure 4-7: Seasonal mid-day dissolved oxygen variations at Selah Creek Lagoon.

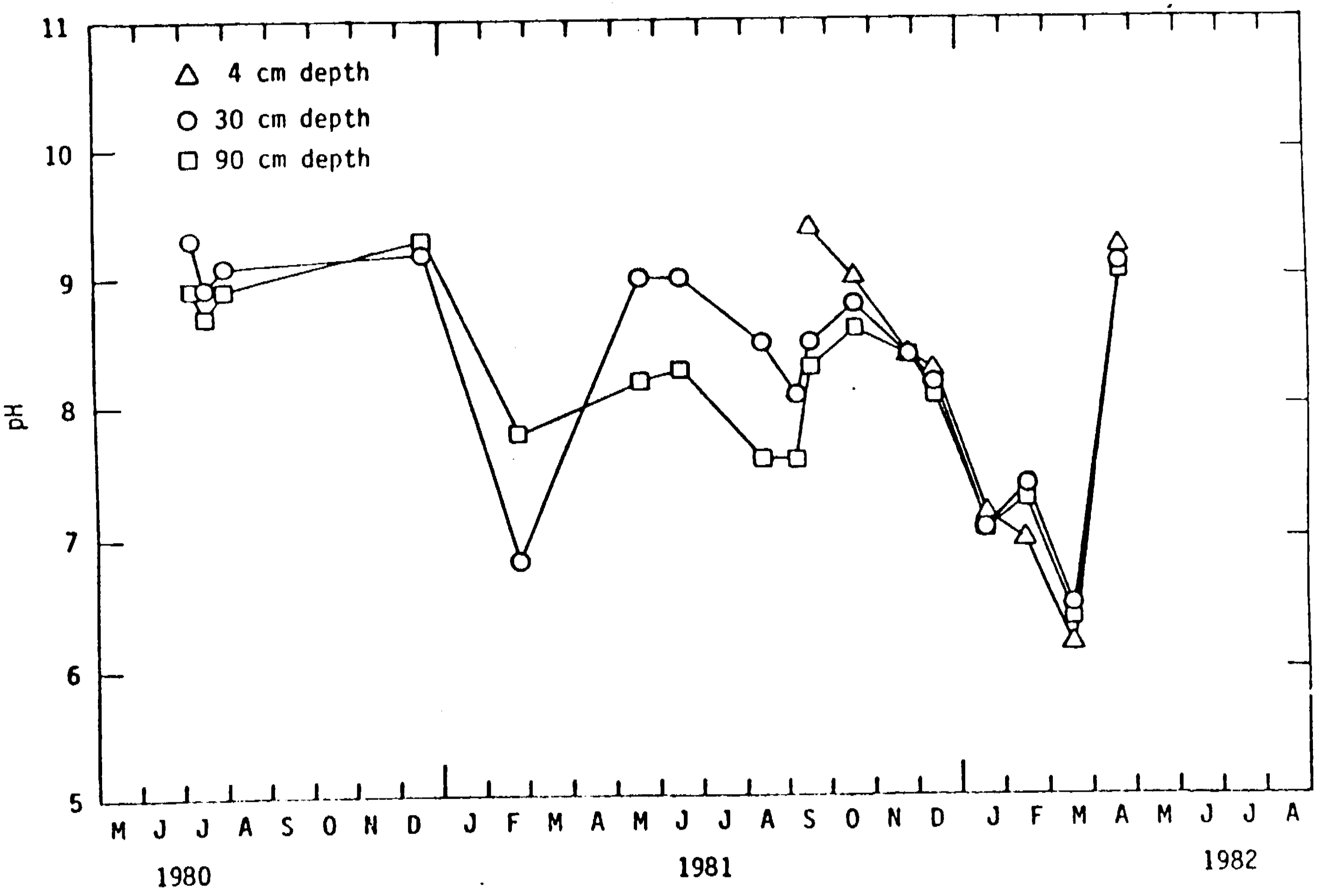


Figure 4-8: Seasonal pH variations at Selah Creek Lagoon.

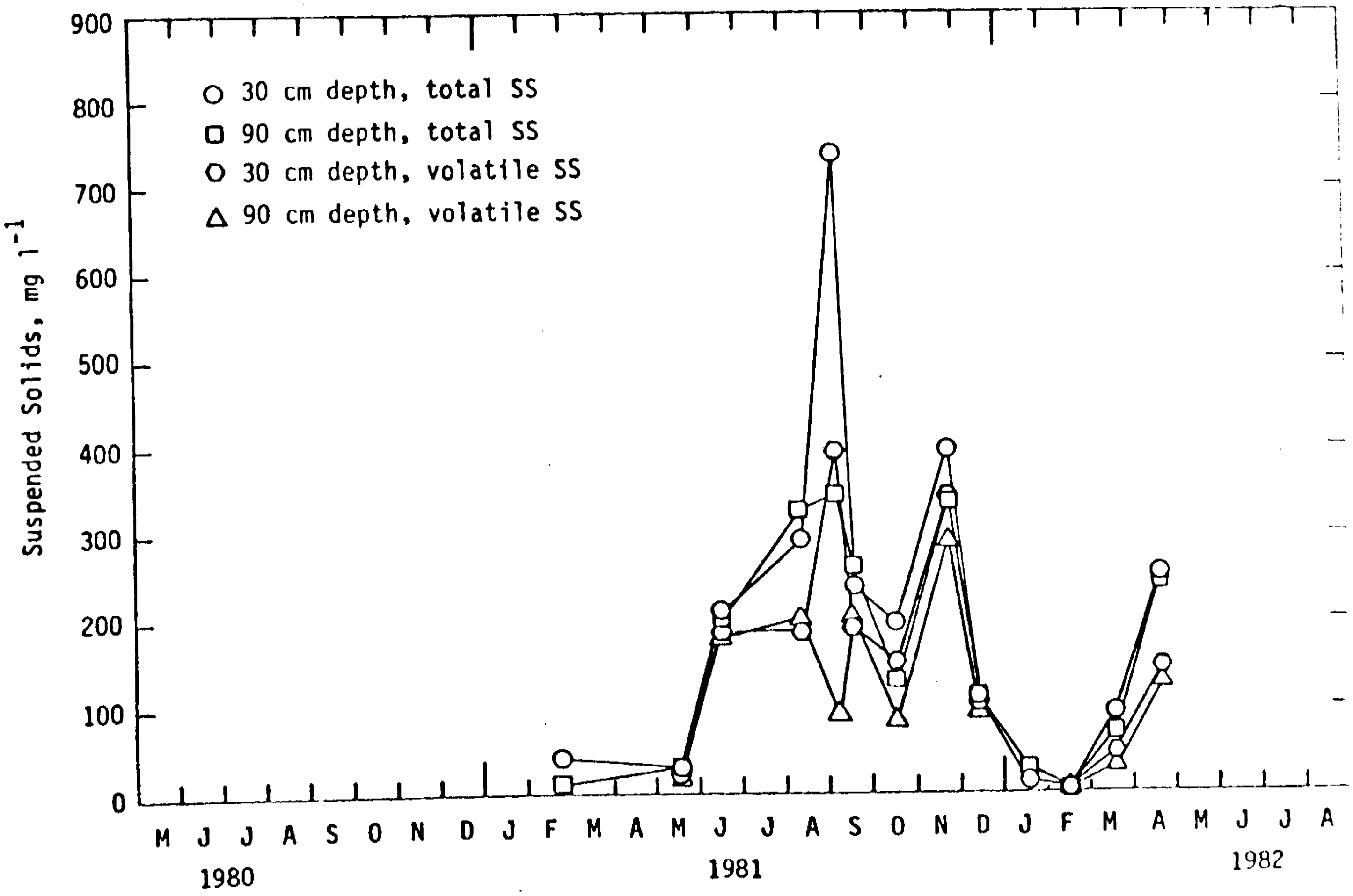


Figure 4-9: Seasonal variations in suspended solids at Selah Creek Lagoon.

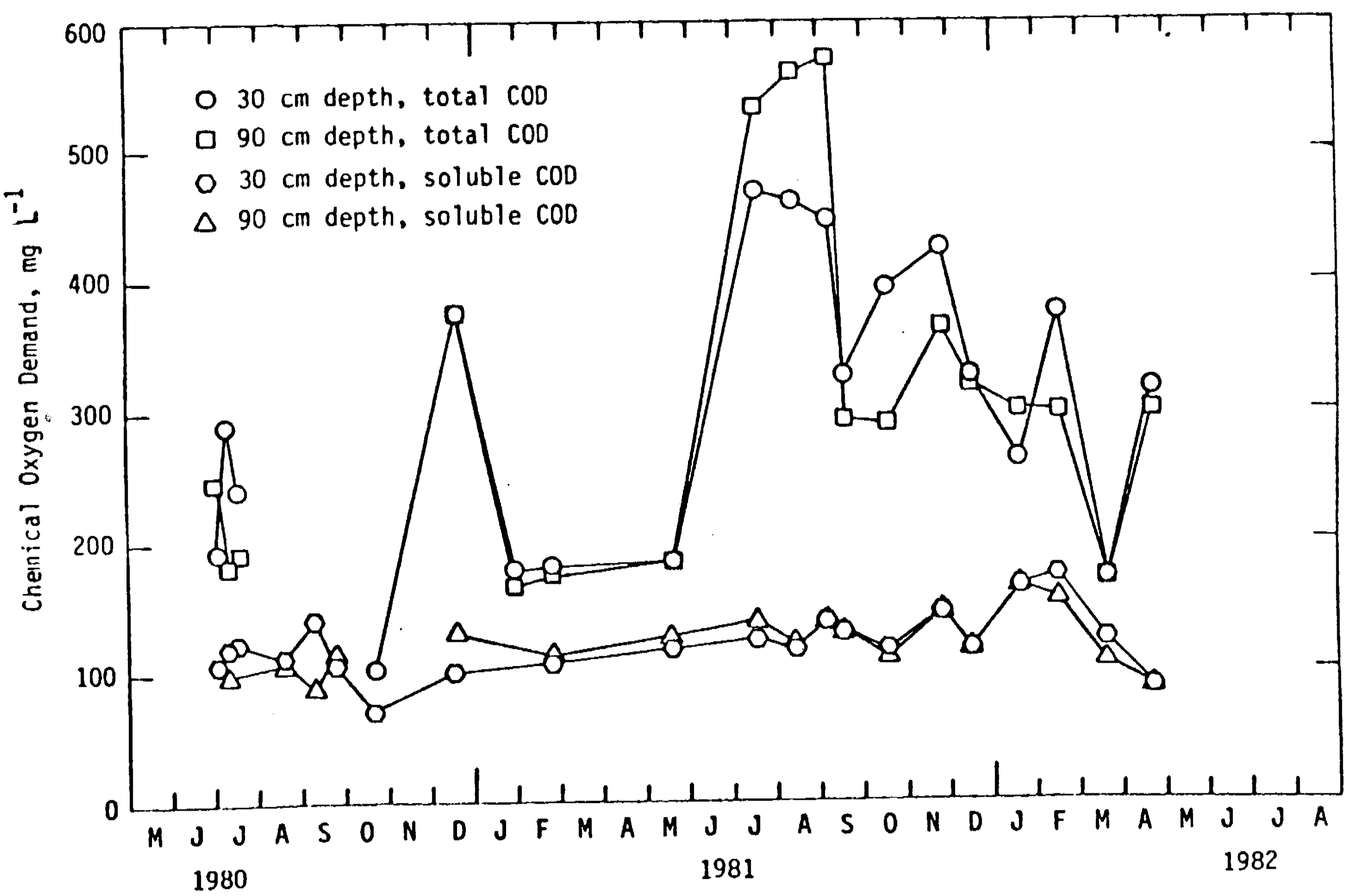


Figure 4-10: Seasonal COD variations at Selah Creek Lagoon.

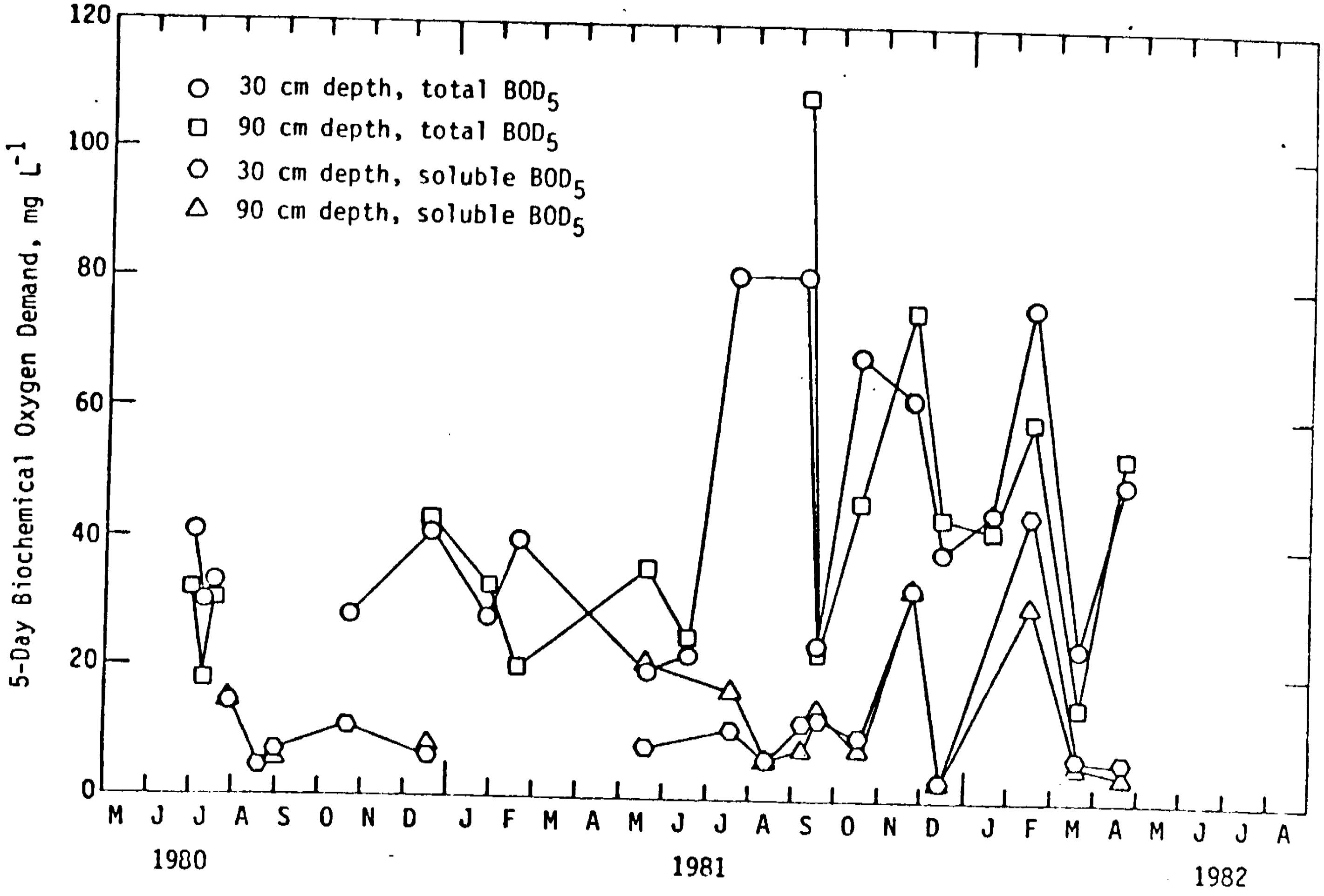


Figure 4-11: Seasonal $BOD_5$ variations at Selah Creek Lagoon.

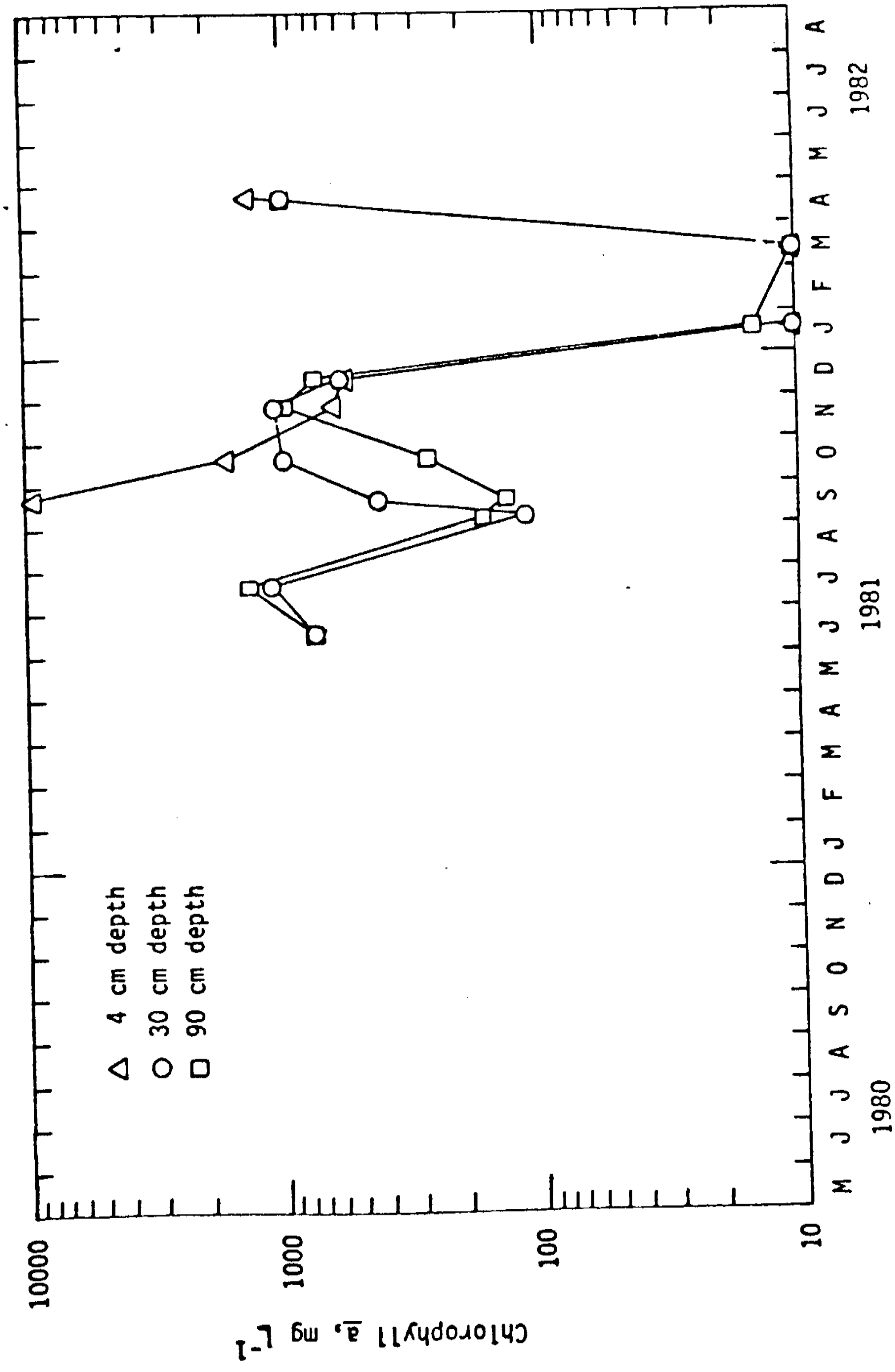


Figure 4-12: Seasonal chlorophyll a variations at Selah Creek Lagoon.

vehicles per day contributes 1280 g (2.8 lb) $BOD_5$ per weekday. This gives a total $BOD_5$ loading of 1.9 g/m$^2$-d (17 lb/acre-day) at Selah Creek, which is acceptable. However, on Labor Day RV waste from about 35 RVs contributed 6550 g (14.4 lb) $BOD_5$ and restroom waste from about 600 vehicles contributed 2080 g (4.6 lb) $BOD_5$ (assuming similar usage rates for eastbound and westbound rest areas). Thus, the combined loading on the lagoon would have been about 6.4 g/m$^2$-d (57 lb/acre-day), which exceeds the design criteria. It was noted that the lagoon had an unusual brown color at the end of the day on Labor Day. The lagoon had very high suspended solids, COD, and $BOD_5$ values for that day.

Nine days after Labor Day, 1981, suspended solids, COD, and $BOD_5$ values were normal. There was a very dense algal bloom, and the lagoon was green with some streaks of brown in it. The chlorophyll <u>a</u> concentration was extremely high in water taken 4 cm (1.6 in) below the surface. The dissolved oxygen concentration 4 cm (1.6 in) below the surface was supersaturated at 30 mg/L. Light penetration, measured with a Secchi disk, was only about 5 cm (2 in). At 30 cm (12 in) depth, dissolved oxygen was 0 mg/L. While the lagoon had experienced an unusually heavy organic loading over the Labor Day weekend, it was versatile enough to absorb the shock and recover.

During the winter of 1981-82, ice and snow blocked all light, and the lagoon became entirely anaerobic under the ice. pH dropped to 7.2. During the spring thaw when ice still covered about 75 percent of the surface, the surface water, which was primarily melting ice-water, was very clear and had 3.3 mg/L dissolved oxgyen. This layer of oxygenated ice-water helped to minimize odors from the anaerobic lagoon. There was a slight fishy odor indicating the presence of amines in the air (Metcalf and Eddy, 1979). The pH had dropped to 6.4 at this time, which would encourage volatilization of odorous compounds.

In April, 1982, a spring bloom of algae appeared throughout the water column and raised the pH and dissolved oxygen levels.

### Dye Accumulation

Figure 4-13 shows the light absorbance spectrum of lagoon water in June, 1981, prior to opening the station. The September and November, 1981 increases in absorbance at a wavelength of 630 nm probably reflect the presence of blue dye from RV additives. Data for summer 1982 show only slight further increase in absorbance at 630 nm. Since the dye is resistant to biodegradation, it may accumulate in the lagoon as more RV waste is added and water evaporates.

An accumulation of blue dye in the lagoon should not pose any significant problems. If the dye is blue food coloring, it probably is not toxic. It could interfere with light penetration if intense enough, but it may take many years to accumulate to significantly affect photosynthesis. Over a period of several years, the dye probably would degrade by biological or physical action, or be removed by adsorption to solids in the lagoon. However, as discussed in the following section, leakage from the lagoon probably limits the buildup of dye and other dissolved materials.

### Lagoon Leakage

Figure 4-14 shows electrical conductivity measurements for the Selah Creek Rest Area water supply, averaging 285 $\mu$mho cm$^{-1}$, and for the lagoon, averaging 1100 $\mu$mho cm$^{-1}$. The conductivity of the lagoon is very low considering that the rest area has been operating for about 10 years and indicates probable loss of dissolved solids by leakage.

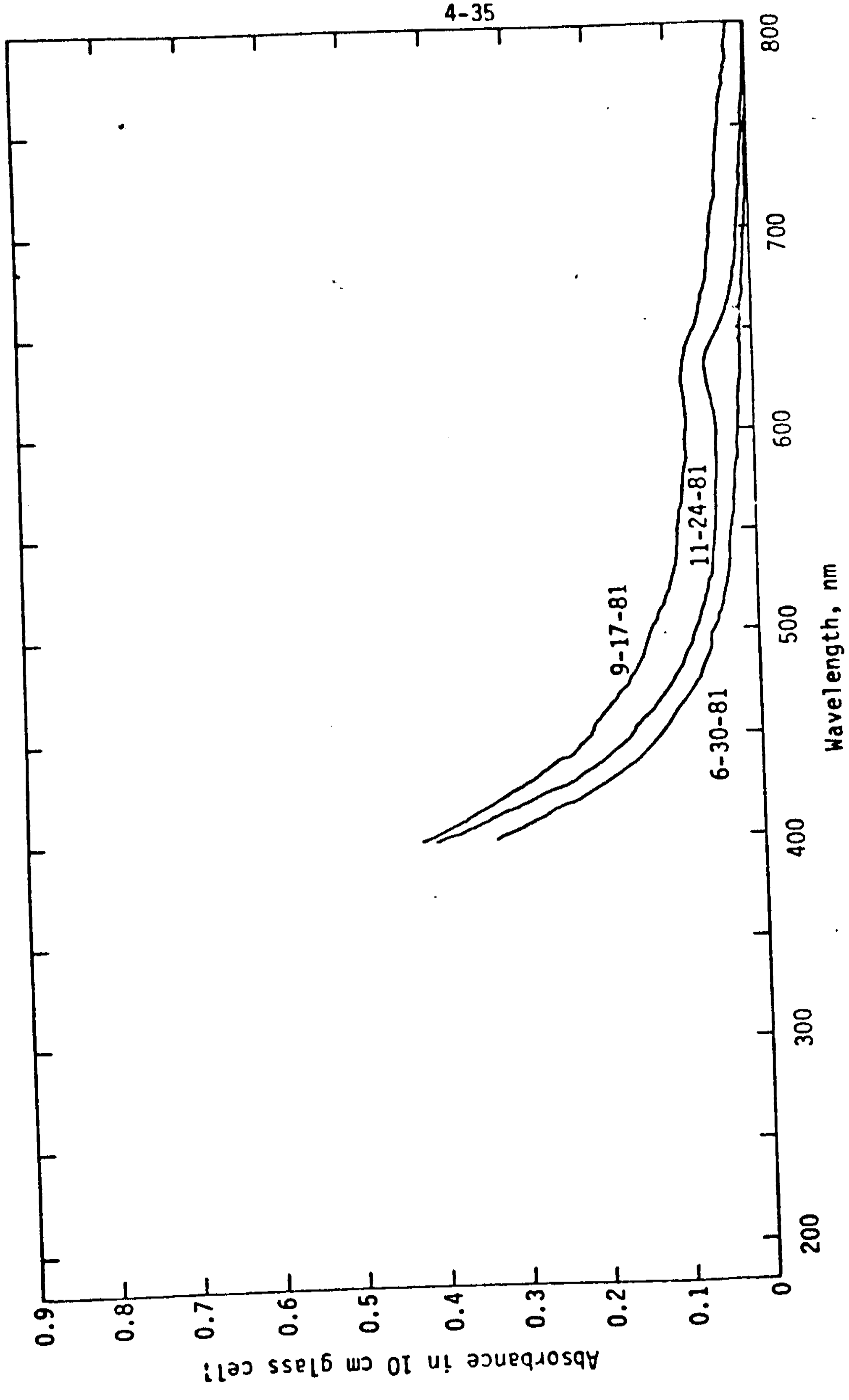


Figure 4-13: Light absorbance spectrum of Selah Creek Lagoon.

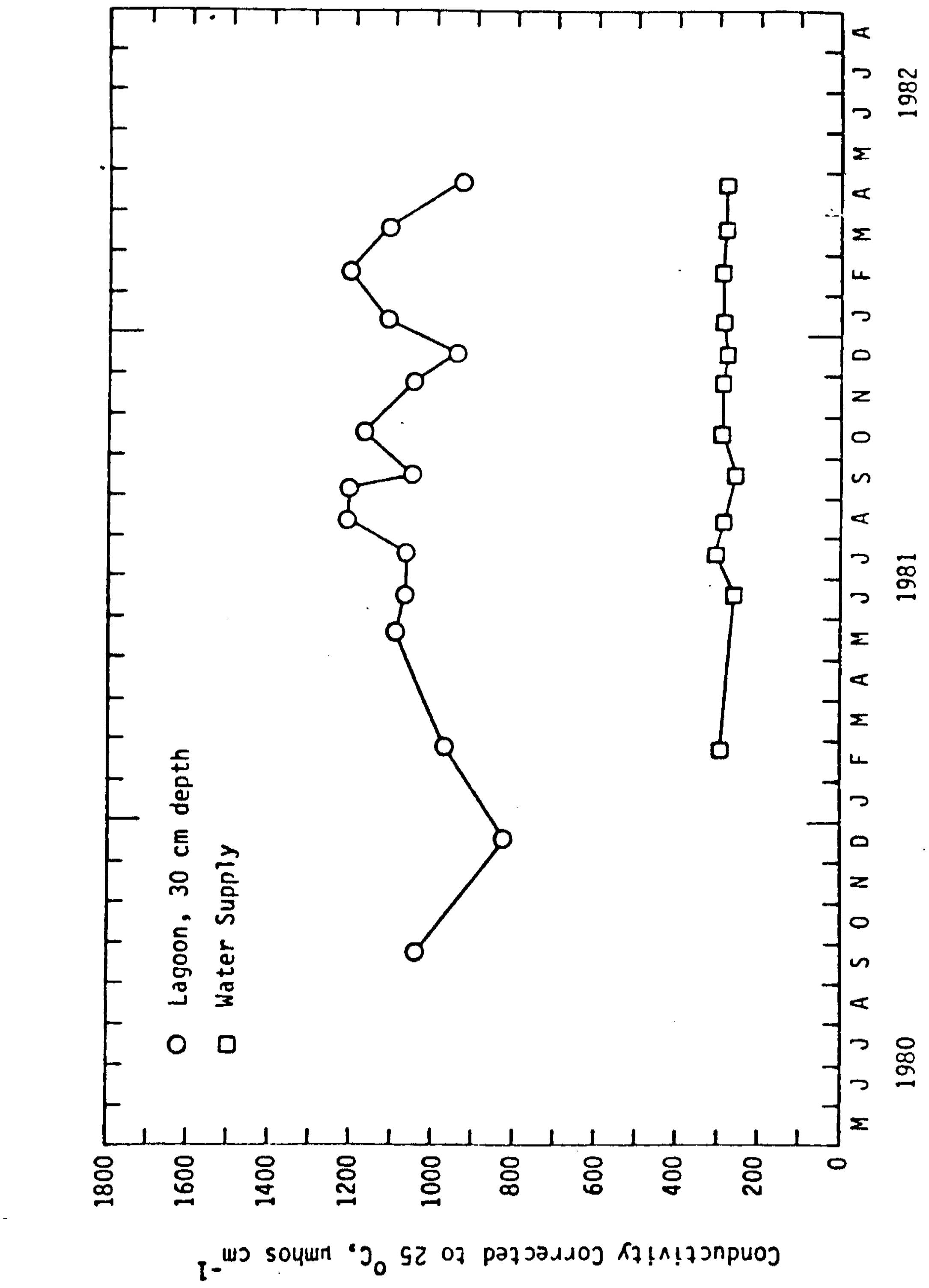


Figure 4-14: Electrical conductivity of Selah Creek lagoon and water supply.

On June 18, 1981, 11.4 kg (25 lb) of lithium chloride were added to the lagoon. Both lagoon and water supply samples were collected on a regular basis and analyzed for lithium concentration using atomic absorption spectroscopy. The results are given in Table 4-5. Figure 4-15 shows lithium concentration in the lagooon as a function of time. A mass balance on lithium can be used to estimate the volume of leakage.

$$[\mathrm{Li}]_{\substack{\mathrm{lagoon}\\ \mathrm{initial}}} \times V_{\mathrm{lagoon}} = [\mathrm{Li}]_{\substack{\mathrm{lagoon}\\ \mathrm{final}}} \times V_{\mathrm{lagoon}} + [\mathrm{Li}]_{\mathrm{leakage}} \times V_{\mathrm{leakage}}$$

$$1.38\ \frac{\mathrm{mg}}{\mathrm{L}} \times 1.64 \times 10^{6}\ \mathrm{l} = 1.13\ \frac{\mathrm{mg}}{\mathrm{L}} \times 1.64 \times 10^{6}\mathrm{l} + 1.26\ \frac{\mathrm{mg}}{\mathrm{L}} \times V_{\mathrm{leakage}}$$

$$V_{\mathrm{leakage}} = 3.3 \times 10^{5}\ \mathrm{L} = 87{,}000\ \mathrm{gal}$$

The average leakage rate during this 83 day period was approximately 4000 L/d (1050 gal/d).

This can be compared with leakage rates estimated from the difference between inflow and evaporation. For 1980 and 1981, estimated leakage rates are 2300 and 2800 ± 1200 L/d (610 and 740 ± 320 gal/d), respectively.

It is concluded that the lagoon is leaking, but it is not known if the leakage is affecting drinking water quality at the Rest Area. Coliform bacteria have been found in the water supply, and the drinking water must be chlorinated. The source of the bacteria may be lagoon leakage, or it may be small animals whose traces have been found in the well.

## Recommended Lagoon Design Procedure

A properly operating lagoon requires healthy populations of aerobic and anaerobic bacteria, algae, and higher microbial life forms. The preliminary indications from our experiments and those of others are that algae may be the

Table 4-5. Selah Creek Lagoon Lithium Tracer Study Results.

| Date | Time From Lithium Addition, days | Lithium Concentration, mg/L Lagoon | Water Supply |
|---|---|---|---|
| 5-17-81 | 0 | 0.01 | 0.012 |
| 6-23-81 | 5 | 1.31 | 0.011 |
| 6-30-81 | 12 | 1.28 | 0.059 |
| 7-03-81 | 15 | -- | 0.010 |
| 7-07-81 | 19 | 1.25 | 0.010 |
| 7-10-81 | 22 | -- | 0.014 |
| 7-16-81 | 28 | -- | 0.014 |
| 7-22-81 | 34 | 1.22 | 0.016 |
| 7-29-81 | 41 | 1.41 | 0.012 |
| 8-05-81 | 48 | 1.23 | 0.011 |
| 8-12-81 | 55 | 1.21 | 0.014 |
| 8-19-81 | 62 | 1.28 | 0.013 |
| 8-26-81 | 69 | 1.24 | 0.012 |
| 9-02-81 | 76 | 1.09 | 0.013 |
| 9-09-81 | 83 | 1.01 | 0.013 |
| 9-16-81 | 90 | -- | 0.013 |
| 12-14-81 | 179 | -- | 0.029 |
| 1-19-82 | 215 | -- | 0.014 |
| 3-19-82 | 274 | -- | 0.021 |
| 4-20-82 | 306 | -- | 0.012 |
| 6-1-82 | 348 | -- | 0.009 |
| 7-19-82 | 396 | -- | 0.013 |
| 8-16-82 | 424 | -- | 0.010 |

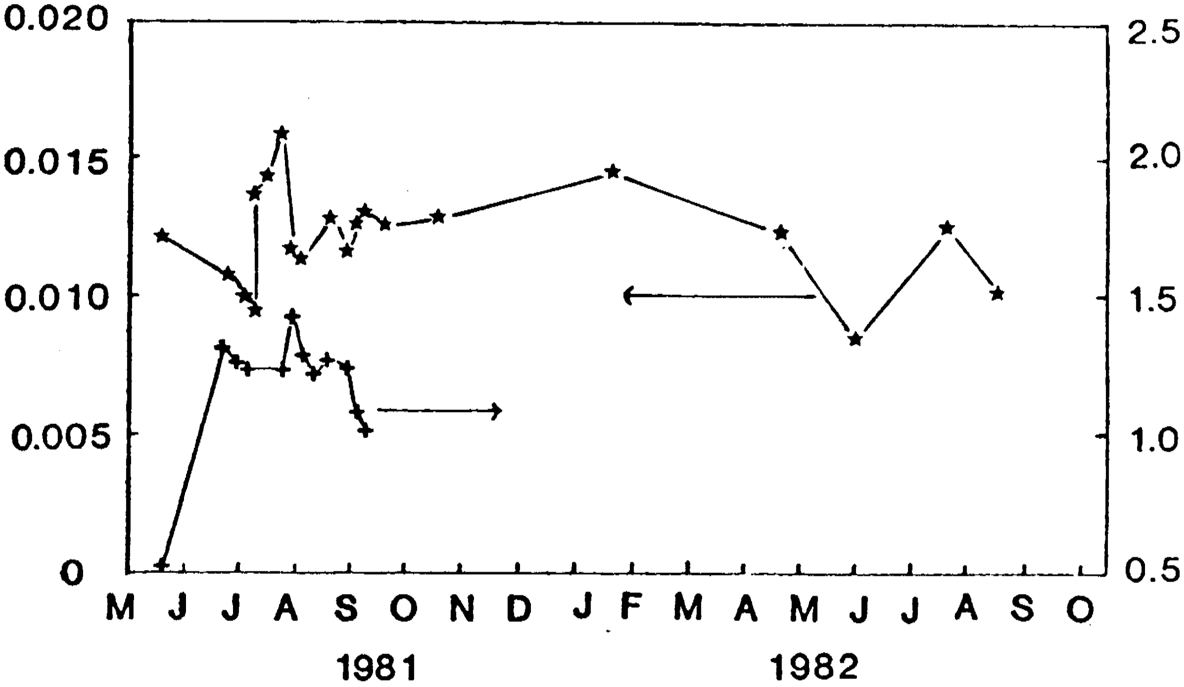


Figure 4-15: Lithium concentration in Selah Creek lagoon and rest area drinking water subsequent to the addition of lithium chloride.

most sensitive of these groups of organisms to formaldehyde. Since formaldehyde can be destroyed by chemical and biochemical reactions in the lagoon and since these reactions are promoted by the presence of other organic matter, we recommend that all lagoons receiving RV wastewater be designed and operated such that the influent includes both RV wastes and preservative-free non-RV wastes. As a further precaution, we recommend that the volume flow rate of non-RV waste be at least five times as great as that from the RVs, using unchlorinated fresh water for dilution if necessary. An obvious and sensible corollary to this recommendation is that, given a choice of where to construct an RV dump station among several highway rest areas in a given geographical area, the rest areas with the higher overall usage rates are preferable. Such a choice may also provide somewhat better protection against illegal use of the dump station.

The areal organic loading on the lagoon will be significantly increased by the BOD from the RV station, and this must also be considered in designing a lagoon treatment system or in evaluating the suitability of an existing lagoon for receiving RV wastes. We feel that the current criteria of 4.5 g BOD/m$^2$-d (40 lb/acre-day) is adequate for sizing lagoons receiving combined RV and non-RV wastes.

The use of these recommendations is demonstrated in the following example for a rest area servicing 20 RV dumps and 400 vehicles per day.

The areal requirement to meet the organic loading criteria is:

$$\text{Area/RV} = (193\ \text{g BOD/RV})/(4.5\ \text{g BOD/m}^2\text{-d}) \qquad = 43\ \text{m}^2\text{/RV-d}\ (460\ \text{ft}^2\text{/RV-day})$$

$$\text{Area/Vehicle} = (3.2\ \text{persons/vehicle})(0.8\ \text{fraction using restroom}) \times (13.3\ \text{L/person})(0.165\ \text{g BOD/L})/(4.5\ \text{g BOD/m}^2\text{-d}) \qquad = 1.2\ \text{m}^2\text{/vehicle-d}\ (13\ \text{ft}^2\text{/vehicle-d})$$

Area required for RV load = (43 $m^2$/RV)(20 RVs/d) = 860 $m^2$ (9270 $ft^2$)

Area required for non-RV load = (1.2 $m^2$/vehicle)(400 vehicles/d) = 480 $m^2$ (5170 $ft^2$)

Total area to meet organic loading criteria = $A_{BOD}$ = 1340 $m^2$ (14,440 $ft^2$)

Next check to see if the non-RV load provides adequate dilution for the RV waste:

Daily flow rate of RV waste = $Q_{RV}$ = (62 L/RV)(20 RV/d) = 1240 L/d (328 gal/d)

Required non-RV flow rate for dilution = 5 x 1240 L/d = 6200 L/d (1640 gal/d)

Daily flow rate from non-RV traffic = $Q_{non-RV}$ =

(0.8 fraction using rest room)(3.2 persons/vehicle) x
(13.3 L/person)(400 vehicles/d) = 13600 L/d (3590 gal/d)

Required dilution water = $Q_{dil}$ = 6200 L/d - 13600 L/d = (none required)

Total flow rate = $Q_{RV} + Q_{non-RV} + Q_{dil}$ =
Q = 1240 + 13600 + 0 = 14800 L/d (3920 gal/d)

Next compute the area necessary to balance the water budget:

$$A_{wat} = Q/(10(E-P)) \text{ (metric units)}$$

$$A_{wat} = 1.6\ Q/(E-P) \text{ (English units)}$$

where A is in $m^2$ or $ft^2$

Q is in L/d or gal/d

E = Evaporation, cm/d or in/d

P = Precipitation, cm/d or in/d

The area requirement for the water balance can then be compared with the area required for the organic load, and the larger of the two is used for design. If $A_{BOD} > A_{WAT}$, the lagoon area will be larger than that required for the water balance. That is, there will be excess evaporation, and additional dilution water will be required. The amount of this extra dilution water will be

$$Q_{Dil,2}\ (L/d) = 10\ A_{BOD}\ (E-P)-Q \text{ (metric units)}$$

$$(gal/d) = (A_{BOD}\ (E-P)/1.6) - Q \text{ (English units)}$$

In choosing the vehicle and RV usage rates to use in the design equations, we recommend the average during the July-August peak period. Designing on this basis rather than the maximum-use day avoids having extremely large lagoons which are almost never used to their capacity. It also is based on the recognition that occasional overloading of the lagoon for one to two day periods does not lead to major problems.

## ACTIVATED SLUDGE TREATMENT PLANTS

In this section we summarize the results of a model of the effects of wastewater from an RV disposal station on a typical activated sludge treatment plant. A typical, well-operated plant was chosen for the analysis. There are, of course, all sizes and types of treatment plant with various modes of operation, and the performance level varies from plant to plant.

The approach of the analysis was conservative in order to demonstrate that only small disruptions are expected to occur with small, well-operated plants, even under severe conditions. Before any treatment plant accepts RV waste, the conditions at that particular plant should be evaluated. The details of the model are provided by Brown (1982).

As discussed previously, mixed aerobic bacterial cultures can acclimate to high formaldehyde concentrations. An acclimated activated sludge system will not be inhibited by the formaldehyde in RV waste. However, RV wastewater generation rates vary widely both with seasons and with day of the week. Therefore, a treatment plant accepting RV waste may not always be acclimated to the transient formaldehyde loading from RV waste on a busy, holiday weekend.

A small activated sludge treatment plant treating a steady flow of typical domestic wastewater containing 220 mg/L $BOD_5$ was modeled. Such a plant may consist of a completely mixed, aerated, activated sludge basin with a hydraulic residence time of 6 hours, a clarifier, and capability for activated sludge recycle and wastage such that the mean cell residence time is 8 days.

It would be desirable for the normal plant flow rate to provide sufficient dilution so that the formaldehyde level in the activated sludge basin is less than 20 mg/L. This would prevent inhibition of unacclimated bacteria. It is likely that, upon dilution in the basin, the formaldehyde concentration will be further reduced by physical and/or chemical reactions with suspended solids and organic compounds (Kiernan, 1982). If the RV waste is generated at the maximum rate from 1 dump station and is mixed continuously with the normal plant influent, the non-RV flow rate would have to be 5250 L/hr (33,000 gal/d) or greater for the desired dilution. The required flow rate would of course vary with the intensity of use of the dump station and whether the RV waste was mixed in continuously or in pulses.

Since the $BOD_5$ of RV waste is about fourteen times that of domestic waste, organic loading from the RV waste must be considered in a small plant. Changes in effluent $BOD_5$ and mixed liquor volatile suspended solids (MLVSS) as a result of RV wastes were modeled using Monod kinetics. Oxygen consumption by carbonaceous oxygen demand, nitrogenous oxygen demand, and endogenous respiration were all considered in the model.

The model scenario and the kinetic parameters used in this example are given in Table 4-6. Typical kinetic parameters for carbonaceous $BOD_5$ removal

## Table 4-6. Parameter Values Used in Activated Sludge Treatment Plant Model

| | | |
|---|---|---|
| Domestic Flowrate | | 5960 L/hr (37,500 gal/d) |
| Domestic Strength, | $BOD_5$ | 220 mg/L |
| | total N | 40 mg/L |
| RV Waste Flowrate: | 9:00 pm to 8:00 am | 0 mg L |
| | 8:00 am to noon | 250 L/hr |
| | noon to 5:00 pm | 700 L/hr |
| | 5:00 pm to 9:00 pm | 350 L/hr |
| RV Waste Strength, | $BOD_5$ | 3110 mg/L |
| | total N | 565 mg/L |
| $\theta$, hydraulic residence time | | 6 hr |
| $\theta_c$, mean cell residence time | | 8 d |

| | BOD Removal | Nitrifying Bacteria |
|---|---|---|
| $K_s$, half-velocity constant, mg/L | 60 | 2.5 |
| k, maximum rate of substrate utilization per unit mass of MLVSS | 5 | 6.67 |
| Y, maximum yield coefficient | | |
| mg VSS/mg $BOD_5$ | | |
| mg VSS/mg $NH_4^+$-N | 0.6 | 0.15 |
| $k_d$, endogenous decay coefficient, $d^{-1}$ | 0.06 | 0.07 |
| S initial effluent substrate concentration, mg/L | 4 | 1 |
| X, initial cell concentration, mg/L | 2800 | 120 |
| $f_d$, degradable fraction of cell | 0.8 | 0.8 |

were taken from Metcalf and Eddy (1979). For nitrification, typical parameters were obtained from Gaudy and Gaudy (1980). Time increments of 15 seconds were used for $\Delta t$. Increments of 30 seconds and longer were found to affect the calculated responses, while increments less than 15 seconds did not affect the results significantly.

The modeled responses to RV transient loading for this example are shown in Figure 4-16. The change in effluent $BOD_5$ is very rapid with most of the change taking place within 15 minutes of a step change in loading. Effluent $BOD_5$ concentration is reduced quickly when the RV waste loading is reduced. A well-operating plant should be able to accommodate this temporary increase in $BOD_5$ in the effluent. A poorly-operating plant may have some trouble.

The changes in MLVSS are much slower, although a definite increase in solids concentration is seen. Although cell growth is relatively rapid, cell loss by endogenous decay is slow. As a result, MLVSS concentration is higher on the second day and the activated sludge can assimilate the increased RV waste organic loading somewhat more rapidly than on the first day.

The Thousand Trails campground near LaConner, Washington, has 250 campsites and two RV waste disposal stations. All campground wastewater including shower and wash water, toilet water, and RV waste is collected in holding tanks, then trucked to the LaConner treatment plant.

The LaConner treatment plant is a well-operated 378,000 L/d (100,000 gal/d) plant with an activated sludge oxidation ditch having a three day hydraulic detention time and a 45 day mean cell residence time.

On May 4, 1981, the LaConner treatment plant influent, basin, and effluent were sampled prior to the unloading of an 8700 L (2300 gal) truckload of wastewater from Thousand Trails. The wastewater in the truck, the influent while the truck was being unloaded, and water in the basin and effluent one

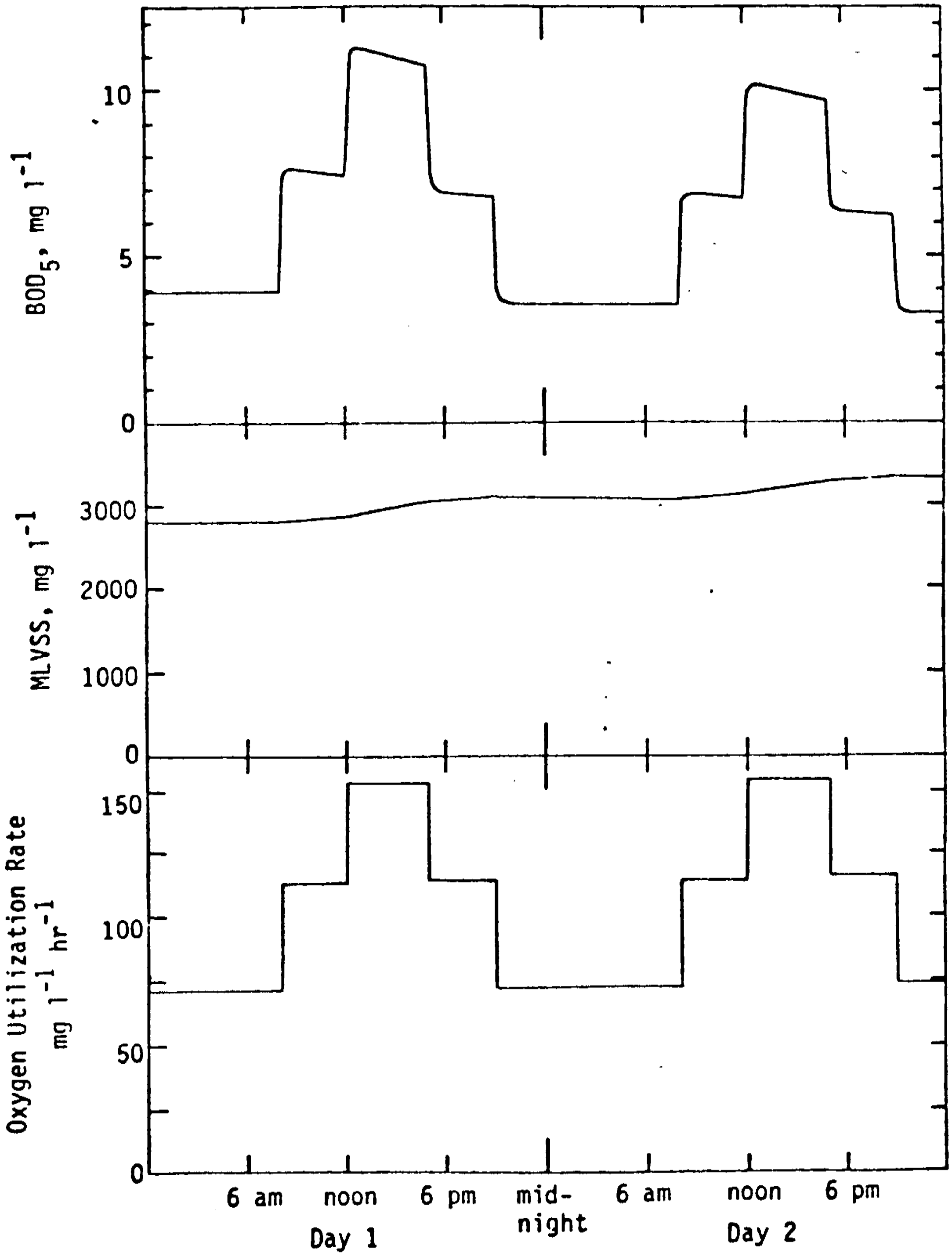


Figure 4-16: Modeled response of an activated sludge treatment plant to a transient input of RV wastewater.

hour after unloading the truck were sampled. The results are given in Table 4-7. The formaldehyde concentration in the campground wastewater was 5 mg/L. At this concentration, no effects from formaldehyde inhibition would have been expected. There was no change in the $BOD_5$ of the effluent one hour after unloading the truck. No operating problems were noticed.

During Memorial Day weekend, May 23-25, 1981, ten 8700 L (2300 gal) truckloads of Thousand Trails wastewater were unloaded at the LaConner treatment plant. On Saturday night, May 23, a toilet valve at the campground stuck in the open position. As a result, the wastewater generated during that weekend was dilute and voluminous. One truckload on Monday was analyzed for formaldehyde. The concentration was below the detectable limit of 1 mg/L. Formaldehye concentrations in the treatment plant basin and effluent were below 1 mg/L on Wednesday, May 27. No operating problems were reported.

During July, 1981, the treatment plant received 780,000 liters of campground waste in 90 truckloads. Again, no operating problems were reported.

Table 4-7. Water Quality in LaConner Treatment Plant During Transient Input of Campground Wastewater including RV Wastewater.

| | COD mg/L | $BOD_5$ mg/L | HCHO mg/L |
|---|---|---|---|
| Prior to Unloading Truck: | | | |
| Influent | 575 | 225 | < 1 |
| Basin | 2450 | 1530 | < 1 |
| Effluent | 50 | 4 | - |
| Wastewater in Truck | 825 | 355 | 5 |
| Influent During Truck Unloading | 845 | 385 | 2 |
| One Hour After Unloading Truck: | | | |
| Basin | 2230 | 1320 | < 1 |
| Effluent | 25 | 4 | - |

# CHAPTER 5: COST-BENEFIT ANALYSIS

## INTRODUCTION

In addition to the technical tasks completed as part of this project, a preliminary economic evaluation was conducted to determine the overall costs and benefits of providing RV dump stations at highway rest areas. This evaluation included consideration of construction costs, maintenance costs including routine maintenance and response to intermittent problems or vandalism, revenues generated, and non-tangible benefits such as convenience to RV owners. This section contains the results of that evaluation.

## DATA COLLECTION

Construction costs for the 10 RV dump stations in operation as of 11/30/82 were provided by the WSDOT. Costs ranged from $31,000-$115,000 and averaged $77,000 per station. This cost includes the cost of plumbing to connect to an existing treatment system, holding tanks, septic tanks or drainfields where needed, or any modifications to the treatment system itself. The cost depends on the location of the dump station and will probably vary in the future over a range as large as that cited above. For the purposes of this evaluation likely low cost and high cost scenarios have been assumed. Dump stations are assummed to have a 20 to 30-year useful life. In the cost-benefit analysis, interest rates are assumed to equal inflation in the low cost scenario and to exceed inflation by 5% in the high cost case.

Routine maintenance is estimated to require 10 to 15 person-hours per week, based on the experience at Wenberg State Park and including a 25% increase based on the assumption that people will be somewhat more careful at a place where they may be staying for a few days than at a highway rest area.

An hourly rate of $17.50 is assumed, based on average costs incurred during the first part of the program. Routine maintenance includes hosing down of the area and occasional correction of plumbing or electrical malfunctions, including clogging of the pipe. One major difference between a highway rest area dump station and one at a state park is that if a problem arises at a state park, the ranger can be summoned in a matter of minutes to either correct the problem or close the station. While this is impossible at a rest area, the phone number of the nearest maintenance station should be prominently displayed at the dump stations, along with a request that people report problems immediately.

The problem of vandalism is also likely to be more serious at highway rest areas than at state parks or private trailer parks. For lack of any good estimate, we estimate the cost of vandalism based on a need to completely replace all above-ground capital equipment and appurtenances every two to three years, including labor ($1100/3years). We include problems such as collision of vehicles with the cabinet holding the water supply hose in this category, as it represents a cost which results from abuse of the system and which could be legally assignable to an individual if he/she were apprehended.

Administrative costs associated with the RV dump stations are considered negligible in the analysis, since no significant change is needed in either the present cost-accounting system or the revenue collection system. Costs of treatment and disposal of the RV wastes are also negligible compared to the other estimated costs.

Revenues to offset the costs of the RV dump stations are generated by a $1 per vehicle surcharge on all recreational vehicles registered in the state. At present, this provides an annual income of approximately $185,000.

The quantifiable costs and revenues associated with the disposal stations are summarized in Table 5-1. The costs are dominated by routine operation and maintenance, a number which is not known with any degree of accuracy. The uncertainty is reflected in a net surplus equal to provision of 4 disposal stations or a net deficiency equal to one station for the low and high cost cases, respectively. This uncertainty in costs in the disposal station program may be resolved in review of the draft report or may require additional operating experience. Although there may be enough surplus to support construction of additional stations, such action should not be taken until either a few years operating experience has been obtained or the State makes a firm decision that increasing the RV license fee surcharge is acceptable. Adequate funds must be budgeted to cover operation, maintenance and vandalism at the disposal stations, and careful records should be maintained to determine real expenses.

The less well-defined costs and benefits of RV dump stations to state residents were assessed by conducting a mail survey. A random sample listing 1000 recreational vehicles and 1000 non-recreational vehicles was collected from the State's register of vehicles, and surveys were sent to owners of those vehicles. Samples of the two survey instruments used are provided in Appendix A. More than half of the people who responded to the survey sent to owners of non-RV's were individuals who also owned an RV. Therefore, the survey summary is split into three categories: respondents to the RV-owner survey, respondents to the non-RV survey who own RVs, and respondents to the non-RV survey who do not own an RV.

Table 5-2 summarizes general information regarding the dump stations and indicates that 50-60% of the RV owners in the state are aware of the highway rest area dump stations and that 25% have used the dump stations. A large

Table 5-1. Costs and Revenues Associated with RV Dump Stations

| Item | Low Estimate Annual Cost Per Station, $ | High Estimate Annual Cost Per Station, $ |
|---|---|---|
| Construction | 2,600(1) | 6,180(4) |
| Vandalism | 1,100(2) | 1,700(5) |
| Operation and Maintenance | 9,100(3) | 13,650(6) |
| Total | 12,800 | 21,530 |
| Total Annual Cost for 10 Dump Stations, $ | 128,000 | 215,300 |
| Total Annual Revenue @ $1/RV,$ | 185,000 | 185,000 |
| Estimated Annual Surplus, $ | 57,000 | ($30,300) |

Notes:

1. ($77,000/station)/30 yrs
2. Replacing above-ground equipment every three years.
3. (10 hrs/week)($17.50/hr)(52 wks/yr)
4. $77,000/station, 20 yrs, 5% interest rate
5. Replacing above-ground equipment every other year
6. (15 hrs/week)($17.50/hr)(52 weeks/yr)

fraction (44%) of the respondents not owning RVs were also aware of the dump stations' existence. Even allowing for the possibility that people knowing about the dump stations might be more likely to respond than those not knowing of them, it seems that awareness that the state has constructed RV dump stations is fairly high.

The most significant item on Table 5-2 is the last entry, indicating that essentially all respondents, whether or not they own RVs and regardless of whether they were aware of the dump stations prior to receiving the survey, thought the dump stations were worthwhile. Certainly some of this approval may have been generated by the wording of the survey; the surveys stated that the dump stations might reduce health hazards and environmental damage and were being paid for exclusively through license fees for RVs. In fact, some respondents indicated clearly that their approval was conditional on this funding mechanism. Even so, there is an important point to be learned from this result. If the goals and funding arrangement of the program are made clear to the general public, non-RV owners strongly support construction of the dump stations. We recommend that a brief "fact sheet" be posted in the non-RV portion of the rest areas explaining these things.

The second setion of Table 5-2 summarizes more specific information about why the respondents view the dump stations as worthwhile. Given a list of choices, reduction of health hazard, reduction of illegal dumping, and convenience to RV owners ranked about equally as major benefits of the dump stations, while cost savings to RV owners was a less prominent benefit. Not surprisingly, RV owners considered convenience to be the major benefit provided by the dump stations more often than did non-RV owners.

The final section of Table 5-2 summarizes data regarding quantifiable costs and benefits for the RV owners. Asked how much they spent during the

Table 5.2. Summary of responses to mail survey assessing citizen reactions to construction of RV wastewater disposal stations.

| | RV OWNERS | | NON-RV OWNERS |
|---|---|---|---|
| | RV Survey | Non RV Survey | |
| Number of Respondents | 289 | 113 | 88 |
| Aware of RV Dump Stations | 146 (51%) | 65 (58%) | 39 (44%) |
| Used RV Dump Stations | 84 (29%) | 28 (25%) | - |
| Are RV Dump Stations Worthwhile? | - | 103Y; 6 N | 84 Y; 0 N |

### MOST IMPORTANT CONSIDERATION

| | | | |
|---|---|---|---|
| Number of Respondents | 263 | 86 | 65 |
| Cost | 4% | 5% | 0% |
| Convenience | 38% | 25% | 20% |
| Reduce Health Hazard | 24% | 30% | 35% |
| Reduce Illegal Dumping | 34% | 40% | 25% |

### RV OWNERS COST DATA

Is $1 Reasonable Fee? Yes 253 (93%); No 20

RV Owners Estimates of:

| Present Cost, $ per Dump | <1 | 1-2 | 4-5 | >5 |
|---|---|---|---|---|
| Number of Respondents | 92 | 35 | 25 | 6 |

| Annual Cost for Dumping, $ | 0 | 1-5 | 6-10 | 11-20 | 21-50 | >50 |
|---|---|---|---|---|---|---|
| Number of Respondents | 95 | 23 | 25 | 22 | 21 | 8 |

| Likely Annual Savings by Using Rest Area Dump Stations, $ | 0 | 1-5 | 6-10 | 11-20 | 21-50 | >50 |
|---|---|---|---|---|---|---|
| Number of Respondents | 63 | 23 | 20 | 17 | 17 | 1 |

| Maximum Reasonable Annual Fee, $ | 0 | 1 | 2-3 | 4-5 | 6-10 | >10 |
|---|---|---|---|---|---|---|
| Number of Respondents | 34 | 52 | 77 | 54 | 11 | 14 |
| Percent of Respondents | 14 | 21 | 32 | 22 | 5 | 6 |

past two years in fees for dump station use, about 60% of the respondents said they spent less than $1.00 per dump station use (most said $0), while most of the others thought they had spent $1-$2 per use. The estimated cumulative cost per year was $0 for about half of the respondents, $1-$10 for another quarter, and more than $10 for the remaining quarter. Except for those spending more than $50 per year in dumping fees, most people felt they would save all the money previously spent in dumping fees by using the rest area dump staions. That is, most people thought it a reasonable possibility that they may do most of their dumping at the rest area stations. It should be noted that many RV parks include the cost of dumping in a lump fee, so RV owners who claim to be spending no money in dumping fees are probably paying some amount for dumping without recognizing it. If RV owners start using rest area dump stations instead of RV parks for dumping, the load on the RV parks would be significantly reduced. Whether the RV parks treat the wastes on-site or pay to haul it elsewhere for treatment, this translates into a cost savings for these RV parks.

RV owners were also asked what they considered a reasonable fee for the service being provided by the State. When told that the present fee is $1 annually, 93% thought this to be reasonable. On the other hand, when asked to state specifically the maximum reasonable annual fee for the serice, 14% responded that no charge, however small, was reasonable. About one-fifth felt that the present $1 annual fee was the maximum reasonable one, about 1/3 considered $2-3 reasonable, and another 1/5 thought $4-5 was reasonable. Only one in nine (11%) were willing to consider a fee greater than $5 reasonable. While these results should be interpreted cautiously, they indicate that, if necessary, the annual fee (and hence the annual revenues) could probably be tripled or possibly even quintupled without overwhelming dissent from potential users. One obvious possibility is that those living near a dump station might find it more valuable and hence reasonable to pay a higher fee than those for whom the stations are less convenient. While this could not be tested, the number of written comments suggesting a station be built near the respondent's home indicates that location of the dump stations is a primary concern of potential users.

Each survey also asked the respondents for additional comments or suggestions regarding the dump stations. Approximately 40% of the respondents wrote some comments, most of which fell into a few categories. On the survey sent to owners of non-RVs, about half the comments reinforced opinions already expressed in the specific questions. The remaining half covered a wide range of opinions, but by far the most common comment related to the source of funds for the dump stations. Many people said they would be opposed to the dump stations if the costs were not borne entirely by RV owners, and others simply expressed cynicism regarding the State's plan to collect all the necessary funds from RV license fees. The widespread concern over this matter should be viewed both as a challenge and as an opportunity by the State. As will be shown, enough revenue can be generated by RV registration fees to cover the construction and operation of the stations, while keeping the fees within the range that most owners consider reasonable. Cost-effective operation of these facilities will satisfy citizen concerns and at the same time build confidence in the State's fiscal management policies.

Comments on the survey sent to RV owners more often reflected concerns about the number and location of dump stations or about the appropriateness of charging owners of RVs for the stations regardless of how often the individual owner used the facility. In the former category, there was strong sentiment for construction of more dump stations, often accompanied by suggested locations based on the respondent's experience and preference. Not surprisingly, there was little agreement on locations for additional dump stations. While these comments should be taken as a general endorsement of the program, little additional information can be gathered from these.

About 15% of the comments on the RV-owners surveys related to perceived inequities in the fee collection procedure. These inequities most often had to do with people who own RVs and either do not plan to or are unable to use the dump stations (e.g. permanently sited trailers). The obvious and most frequently offered solution to this is to charge fees at the dump station each time it is used. While this would certainly address the equity issue and would sharply reduce vandalism, it would not be cost effective unless unacceptably high fees were charged. Furthermore, this would prevent the dump stations from being open continuously, which was noted as a significant benefit by several people. It does seem that owners of "non-mobile RVs" should be exempted from the supplemental charge for the dump stations if this can be done in an inexpensive fashion. Perhaps if these vehicles cannot be identified a priori during the billing process, a refund procedure can be established.

The other concern regarding equity that was expressed by several RV owners was that out-of-staters are able to use the system without charge. While this is a legitimate observation, there is no practical method to correct the inequity.

## MAINTENANCE PROBLEMS

A large number of practical problems have arisen associated with the maintenance of the RV dump stations during the past two years. These are detailed in listS prepared by Mr. Larry Kegg and Mr. G. Rhodes, attached as

Appendix B. For the majority of these, obvious corrective measures exist. For others only experience will suggest the best response. In some cases, there is no alternative to occasional unpleasant maintenance assignments.

It should be pointed out that one type of problem, encompassing items 22-24 in Appendix A is qualitatively different from the others. Whereas the other problems generally make usage of the dump station itself difficult or impossible, improper use of the station for dumping septic tank wastes or chemical or hazardous wastes has the potential of inactivating the entire waste treatment system for long periods of time. At present, it appears to be legal to dump septic tank wastes at the RV dump stations, and this matter should be considered by the appropriate regulatory group. Even if such dumping is proscibed, the 24-hour access and the physical isolation of the dump staions make them highly susceptible to illegal dumping. Other than strongly worded warning signs and adequate lighting, there appears to be little that can be done to prevent this practice without severely reducing the benefits of the stations to legitimate users. Since the potential costs of illegal dumping are massive, any reasonable measures that can be taken to discourage it should be taken.

# ACKNOWLEDGEMENTS

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# APPENDIX A

# SURVEY FORMS

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

*Department of Civil Engineering*

Many recreational vehicles such as motorhomes and campers have holding tanks, where toilet water and other wastewater is stored. The Washington State Department of Transportation (WSDOT) has constructed waste disposal stations at selected highway rest areas as a convenience to recreational vehicle (RV) owners and to reduce the likelihood that RV holding tanks will be emptied in places where they may present an environmental health hazard. RV owners pay a $1.00 annual fee for design, construction and maintenance of dump stations.

This mail survey is being conducted among a small sample of vehicle owners in the State to find if the program is known to RV and other vehicle owners. The survey is being conducted by researchers in the Environmental Engineering and Science Program, Department of Civil Engineering, University of Washington, to find if non-RV vehicle owners recognize benefits and costs of the dump stations. Your cooperation in completing the questionnaire will be greatly appreciated. Please return it in the postage paid envelope within seven days. All replies will be kept confidential.

## HIGHWAY REST AREA - RV DUMP STATION SURVEY

1. Do you own or have you used a recreational vehicle (RV)? Yes___ No ___

   If so, what types (e.g., motor home, camper trailer, trailer home)?

   ______________________________________

2. a. Did you know that the Department of Transportation has established waste dump stations for RVs at highway rest areas? Yes___ No ___

   b. If yes, how did you find out?

   highway sign ( )
   noticed while at rest area ( )
   newspaper or radio ( )
   RV organization ( )
   word-of-mouth ( )
   Other ______________________

   c. Have you used a highway rest area RV Dump Station? Yes___ No___

3. Do you think these stations, which are funded by RV user fees, are a worthwhile service? Yes___ No___

   Please comment: ______________________________________

   ______________________________________________________

   ______________________________________________________

4. Among the statements listed below, please check whether you agree or disagree, and by marking the scale from 0 to 4 indicate whether you think the statement is a very important consideration (4); fairly important (3); slightly important (2); unimportant (1), no opinion or don't know (0).

| | Agree | Disagree | Importance (0, 1, 2, 3, 4) |
|---|---|---|---|
| a. Highway Rest Area dump stations will reduce the cost of waste disposal for RV users. | ( ) | ( ) | 0 1 2 3 4 |
| b. Highway Rest Area dump stations are a convenience to RV users. | ( ) | ( ) | 0 1 2 3 4 |
| c. Highway Rest Area dump stations may be used for improper disposal of chemical or toxic wastes. | ( ) | ( ) | 0 1 2 3 4 |

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

*Department of Civil Engineering*

The Washington State Department of Transportation (WSDOT) has constructed RV waste disposal stations at several highway rest areas. Ten sites (listed below) have been completed and are operational.

Waste Disposal Stations at Highway Rest Areas are:

| | |
|---|---|
| Sea-Tac Rest Area | I-5 northbound |
| Silver Lake Rest Area | I-5 southbound |
| Gee Creek Rest Area | I-5 both directions |
| Selah Creek Rest Area | I-82 both directions |
| Winchester Wasteway Rest Area | I-90 both directions |
| Schrag Rest Area | I-90 westbound |
| Sprague Lake Rest Area | I-90 eastbound |

A group at the University of Washington is surveying automobile and recreational vehicle owners in order to help WSDOT determine the benefits and costs of the waste stations. This mail survey is being conducted of a small sample of vehicle owners in the state. Your cooperation in completing the questionnaire will be greatly appreciated. Please return it in the postage paid envelope within seven days. All replies are confidential.

## RECREATIONAL VEHICLE OWNER SURVEY

1. What type of RV do you own (e.g., motorhome, trailer home, camper trailer)? ____________________

2. Does your RV have a shower? Yes___ No___
   a sink? Yes___ No___
   toilet facilities? Yes___ No___

3. How many axles does your RV have, including the towing vehicle? _______

4. How often do you take trips in an RV in the various seasons?

| | Summer | Autumn | Winter | Spring |
|---|---|---|---|---|
| Continuously | ( ) | ( ) | ( ) | ( ) |
| One or more extended trips | ( ) | ( ) | ( ) | ( ) |
| Nearly every weekend | ( ) | ( ) | ( ) | ( ) |
| About Once a Month | ( ) | ( ) | ( ) | ( ) |
| Seldom | ( ) | ( ) | ( ) | ( ) |

5. Did you use your RV on the following major holidays in either 1980, 1981 or 1982 to date? (Please check if yes.)

   Christmas - New Year ( )
   Memorial Day ( )
   Independence Day ( )
   Labor Day ( )
   Memorial Day ( )
   Other (please explain) ____________

6. During a trip how frequently do you usually dump your holding tanks? approximately every ______ days

7. What additive products have you used recently in your holding tank? (Brand Name of product) ________________

8. Did you know that highway rest area dump sites have been opened in Washington? Yes ____ No ____

   If so, how did you find out about them?

   Highway Sign ( )
   Word of mouth ( )
   Newspaper or radio ( )
   RV organization ( )
   Noticed while at rest area ( )
   other ______________________________

9. Have you used the highway rest area dump sites in Washington? Yes___ No___

   Have you used rest area dump sites in other states? Yes___ No___

   Which states? ________________

| | Agree | Disagree | Importance (0, 1, 2, 3, 4) |
|---|---|---|---|
| c. Highway Rest Area dump stations may be used for improper disposal of chemical or toxic wastes. | ( ) | ( ) | 0 1 2 3 4 |
| d. Highway Rest Area dump stations will reduce holding tank dumping along the road side | ( ) | ( ) | 0 1 2 3 4 |
| e. Highway Rest Area dump stations will reduce dumping into sewers & storm drains. | ( ) | ( ) | 0 1 2 3 4 |
| f. Highway Rest Area dump stations will reduce potential health hazards from toilet wastes improperly dumped. | ( ) | ( ) | 0 1 2 3 4 |
| g. Roadside dumping is not very widespread in Washington. | ( ) | ( ) | 0 1 2 3 4 |
| h. Highway Rest Area dump stations may be subject to excessive vandalism | ( ) | ( ) | 0 1 2 3 4 |

17. In your opinion, of the potential benefits listed above, is the greatest benefit of the highway rest area dump sites? a___, b___, c___, d___, e___, f___, g___.

18. Are there any other potential benefits or disadvantages of rest area dump stations that you can think of? Please describe______________________

______________________________________________________________

19. The Highway Rest Area dump stations are currently financed by a $1.00 per year license tab fee on recreational vehicles. Do you think this is a reasonable fee? Yes ____ No ____

20. If costs of construction and operation of the dump station exceed the special license tab revenues, additional funds will be required. Please indicate what maximum amount you would be willing to pay as an annual special RV tab fee. ______________ dollars/year

21. Any comments or suggestions. ______________________________________

______________________________________________________________

**THANK YOU!**

# APPENDIX B

# MAINTENANCE PROBLEMS

[illegible]
DIST [illegible]
[illegible]
[illegible]

## R.V. DUMP STATIONS

### SILVER LAKE and SEA-TAC REST AREAS
(Many Compliments from Travelers.)

4 MAIN ITEMS of CONCERN:

1. Sewer lines plugged from bottles, cans, diapers, sanitary napkins, paper, and trailers plastic dumping hoses.
2. Cabinet reel hoses pulled off or cut by vandals. . The cabinets are not built for easy maintenance.
3. Clean out areas at "Goose Neck" not large enough for proper maintenance.
4. Water puddles around sanitary tank hatch or "Flapper".

POSSIBLE SOLUTIONS for 4 MAIN ITEMS of CONCERN:

1. Present sewer lines at both R/V Dump stations have been plugged many times from the "Flapper" clear past the "Goose Neck".

   A suggestion was made to construct future R/V stations with a 6" PCV sewer pipe instead of 4" sewer pipe. This also includes a larger sanitary tank hatch and larger "Goose Neck" and then connected directly to the sewer line.

   One of the worst items to plug a sewer line is a trailers plastic 8' or 10', dumping hose. These hoses have gone completely thru the small sewer lines and plug up the larger 12" sewer lines at the main rest areas. At the Sea-Tac rest area they have gotten as far as 1500 feet from the R.V. Dump station before plugging the sewer lines.

   It then requires a major operation to remove these pipes and the costs run anywhere from $150.00 to $700.00. Not counting maintenance and labor.

   In order to keep these hoses from accidentally getting into the sewer lines it may be possible to raise the "Flapper" lid. Approximately 4" and inserting a steel rod thru the plastic or iron pipe directly below the flapper and at a angle, so that the solid wastes could still pass.

   Holes could be drilled at the level of the cement floor so that rain water could go down the sewer line.

2. Purchase different or rework present types of cabinets. (Hose guardian model-80-37.) Present models cannot be opened enough to repair the hose on the reel. Put a door on the side or make cabinets bigger.

3. Contruct larger cleanout areas at Goose-Neck. Goose-Necks are too close to side and bottom of clean-outs.

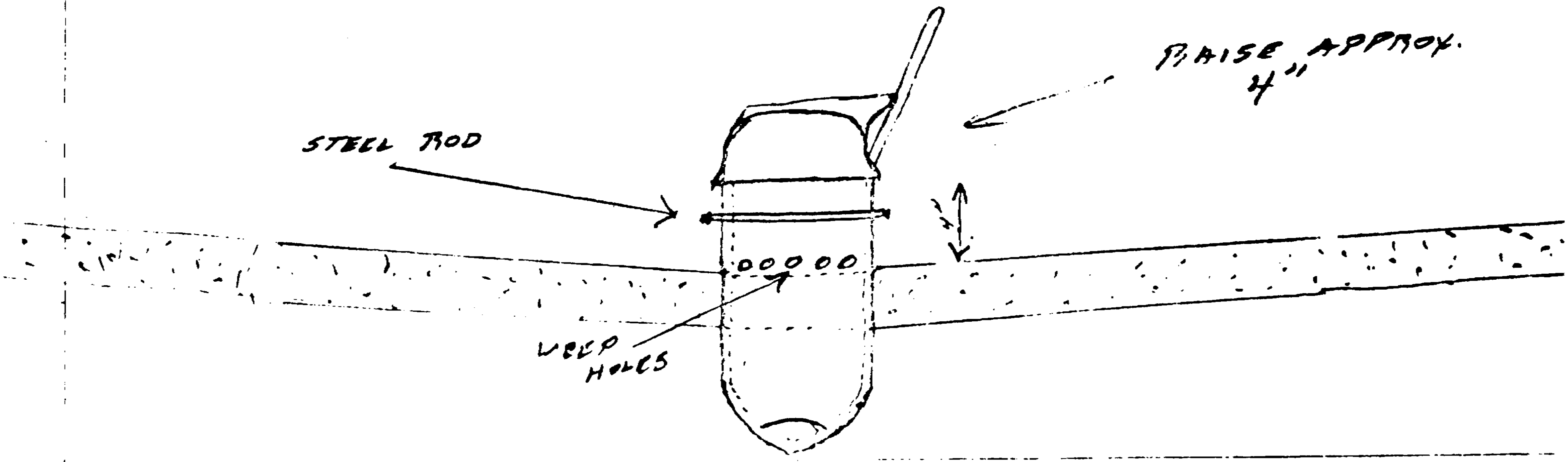
4. Drill ¼" or ½" holes around base of flapper lid.

MISC. CONCERNS:

1. Foam cell insulation on inside of cabinets are not applied to all surfaces.

2. Make sure inspection is made!

# SANITARY TANK HATCH.



December 2 1982
Larry [illegible]

**Plugging:**

1. Rocks and sticks
2. Bottles and cans
3. Hose (4" drain type)
4. Garbage - rags, cups, plastic, etc.

No way to remove trap - Need unions.

Maintenance Problems

1. Only 1 in 10 can be tested for annual backflow protection. Department now in violation of State law.

2. Difficult to work inside cabinets to replace hose, heaters, etc. No room.

3. Difficult to read water meters. Inaccessible.

4. Water meters (some were in gallons/100 gallons and cubic feet.)

5. People back into location - 4 hits on cabinets, one complete knock over. Difficult to repair when wires and pipe broke off at ground line. Need protective post all around.

6. Heaters insufficient to prevent freezing.

7. Main supply line too shallow - freezes - Maintenance complained to P.E. during construction.

8. No manual for source of materials. Bad valves - timers - heaters (some not hooked up.)

9. Contractor installed wrong insulation (wrong R value)

10. Improper installation of insulation, gaps, etc.

11. Foam insulation shot into backflow test cock, backflow exhaust valve, and drain valve.

12. Backflow device discharges into heater - steam.

13. Backflow device discharge and freezes inside cabinet.

14. People steal hose etc.

15. No hose, no wash down. People then dump on pad and will not wash down. If no wash hose, people will not use their 4" drain hose.

16. Frozen effluent on pad.

17. Locked cover down - then dumped on top.

18. People will not clean up mess.

19. Roadway drains away. Spills on roadway drain to curb. No curb drain.

20. Self closing lid after dumping people will rinse out their 4" hose but will not hold cap open with foot. Use rock or not at all. Rinse water then builds up over lid. No drain.

21. No manuals for material source. Difficult to find parts or replacement items.
    Same as 8.

22. Dumping oil into Gee Creek, R.V. dump.

23. Chased "Industrial Waste Disposal" truck from Gee Creek.

24. Septic tank pumpers are dumping.

25. Heaters not hooked up to electrical lines. Maintenance hooked up and heaters caused G.F.I. to trip. Could not keep on. Sprague Lake, Schrog.

26. Timer failure on push button. (Silver Lake).

27. People kick cabinet walls and door in. Gee Creek.

28. Must unlock one side of panel, spring open, then lock and remove key to unlock second lock. Same with closing cabinet.

29. G.F.I. trips when cabinet is hit hard. Bump with hand. (Winchester).

30. Orion $50.00 minimum order for repair parts. Only need a $1.50 gasket.