THE EFFECTS OF HOME WATER SOFTENER REGENERATION WASTES ON SEPTIC TANK SYSTEM PERFORMANCE

by

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CHAPTER I

INTRODUCTION

On-site household sewage disposal employing a conventional septic tank - soil absorption system (ST-SAS) is utilized by 16.6 million housing units (more than 24.5% of all housing units) in the United States according to data gathered in the 1970 United States Census (59). Figure 1 shows the distribution of on-site septic systems by state. This number is growing due in great part both to population movement to rural areas by retired persons and by movement of families following industries to outlying urban areas of metropolitan cities not served by public sewerage facilities (2).

A properly designed, installed, and maintained septic tank serves several important functions in wastewater treatment including solid-liquid separation, storage of solids and flotable materials and anaerobic treatment of both stored solids as well as non-settleable materials. The aforementioned functions of the septic tank serve as pretreatment of the wastewater for its ultimate infiltration into the soil by means of an adequately designed drainfield.

Many households employ point of use water softening

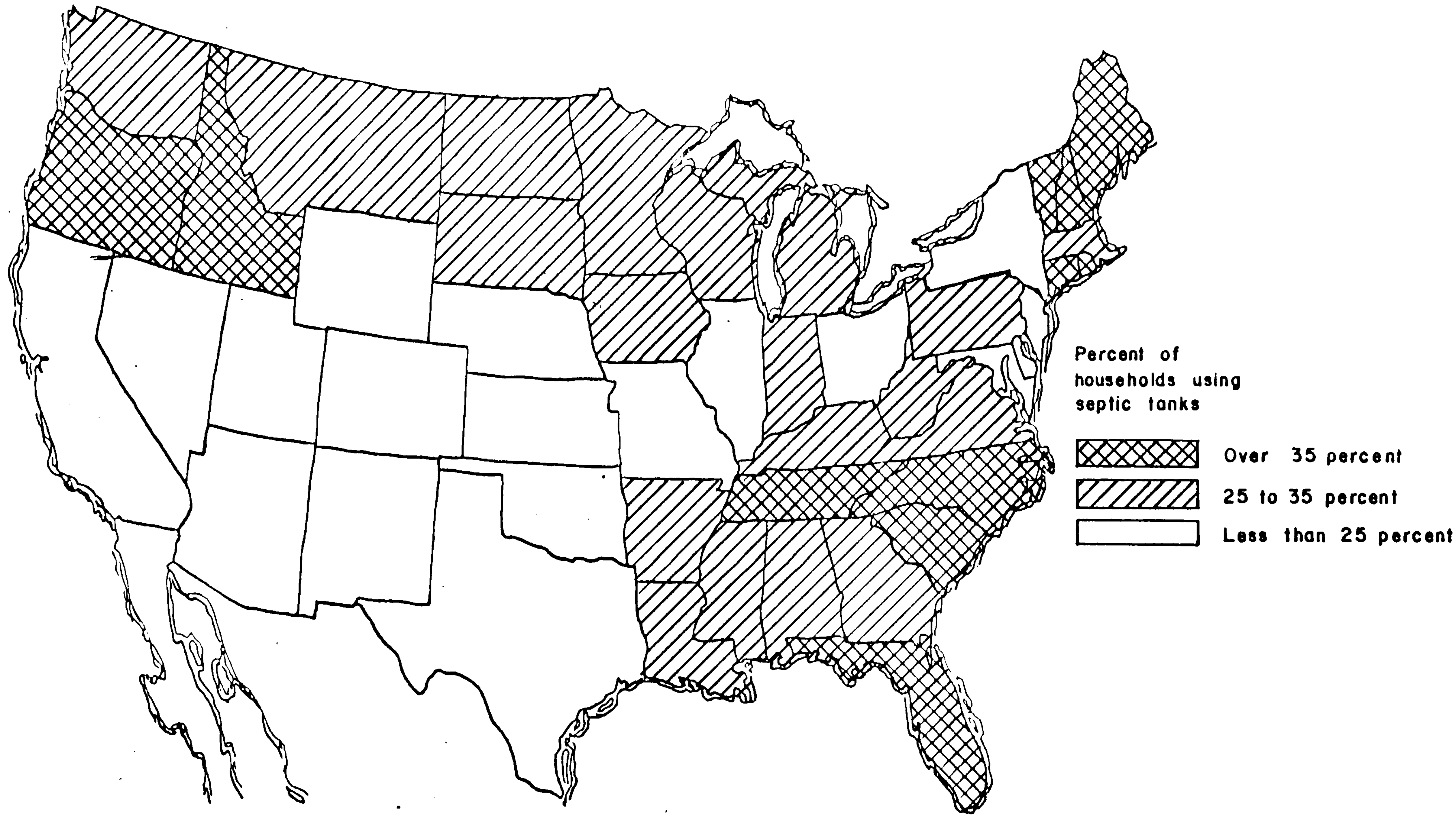


FIGURE 1 DISTRIBUTION OF ON-SITE SEPTIC SYSTEMS, BY STATE (65)

to reduce the hardness of their water supplies. Hardness is defined as a characteristic of water which indicates the total concentration of magnesium and calcium ions expressed as calcium carbonate ($CaCO_3$) (5,4). Concentrations for hardness in mg/l as $CaCO_3$ and the corresponding degrees of hardness are shown in Table 1. Hardness characteristics of United States public water supplies are shown in Figure 2. However, it should be noted that not all households using a septic tank receive their water from a public supply. Many of these households obtain their water from private sources, such as wells. Figure 3 shows groundwater quality in the United States represented by hardness concentrations in mg/l as $CaCO_3$.

From a consumer's point of view, it is desirable to soften water for primarily aesthetic reasons. Soap film is reduced both in personal and household cleaning, and objects are cleaned better with soft water than with hard water. More importantly, soft water protects plumbing from the rigors of hard water scale deposits. Thus, the expected lifetime of plumbing and water using appliances is increased over that of appurtenances subjected to hard water. For example, in Lubbock, Texas, municipal water contains hardness in excess of 250 mg/l as $CaCO_3$, and water heaters require replacement at intervals of 5 to 7 years as opposed to the thirteen years which was found

TABLE 1

CLASSIFICATION OF DEGREES OF HARDNESS OF WATERS (51)

mg/l as $CaCO_3$	Degree of Hardness
0 - 75	Soft
75 - 150	Moderately Hard
150 - 300	Hard
300 up	Very Hard

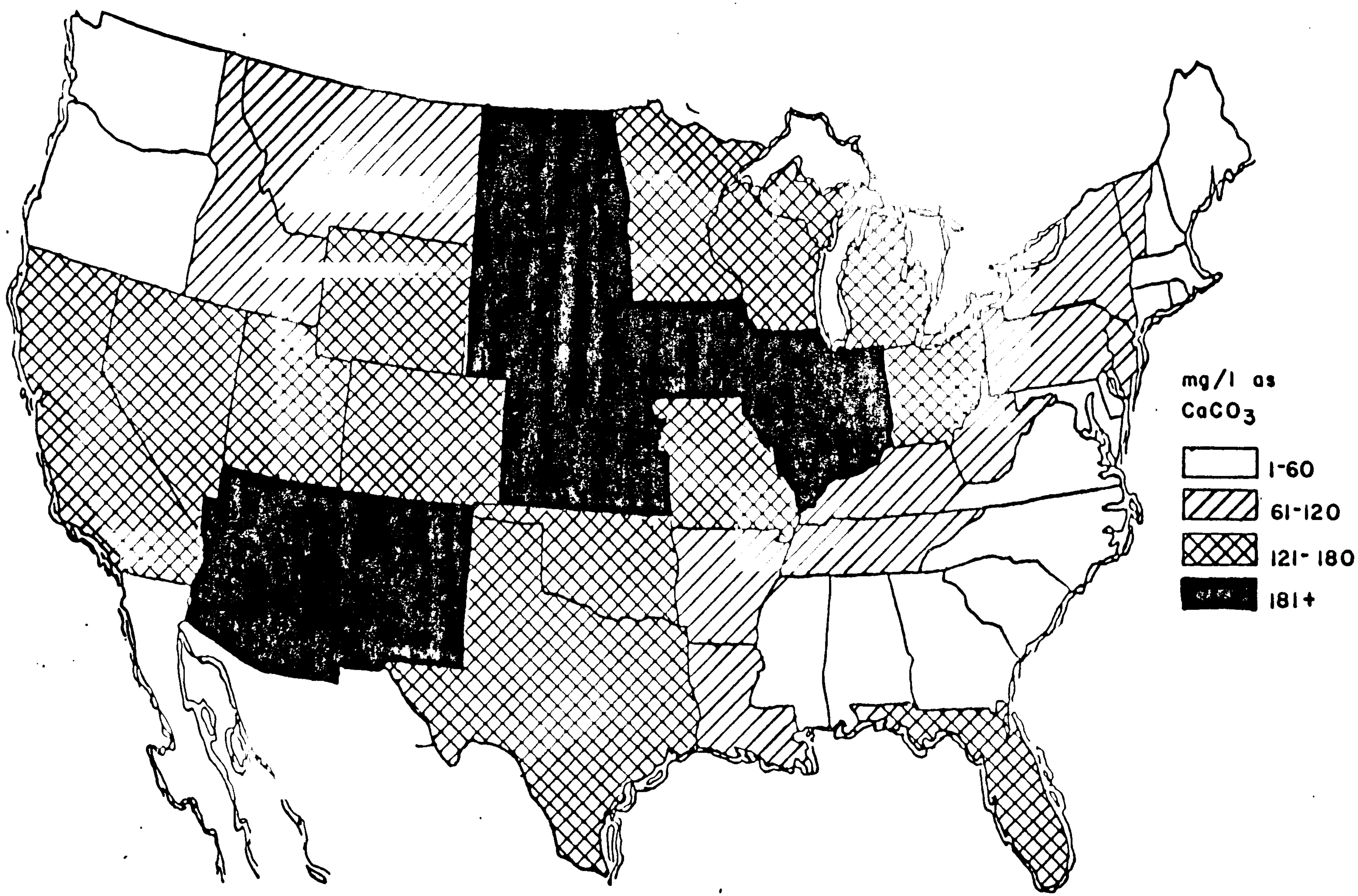


FIGURE 2 HARDNESS CHARACTERISTICS OF U.S. PUBLIC WATER SUPPLIES (47)

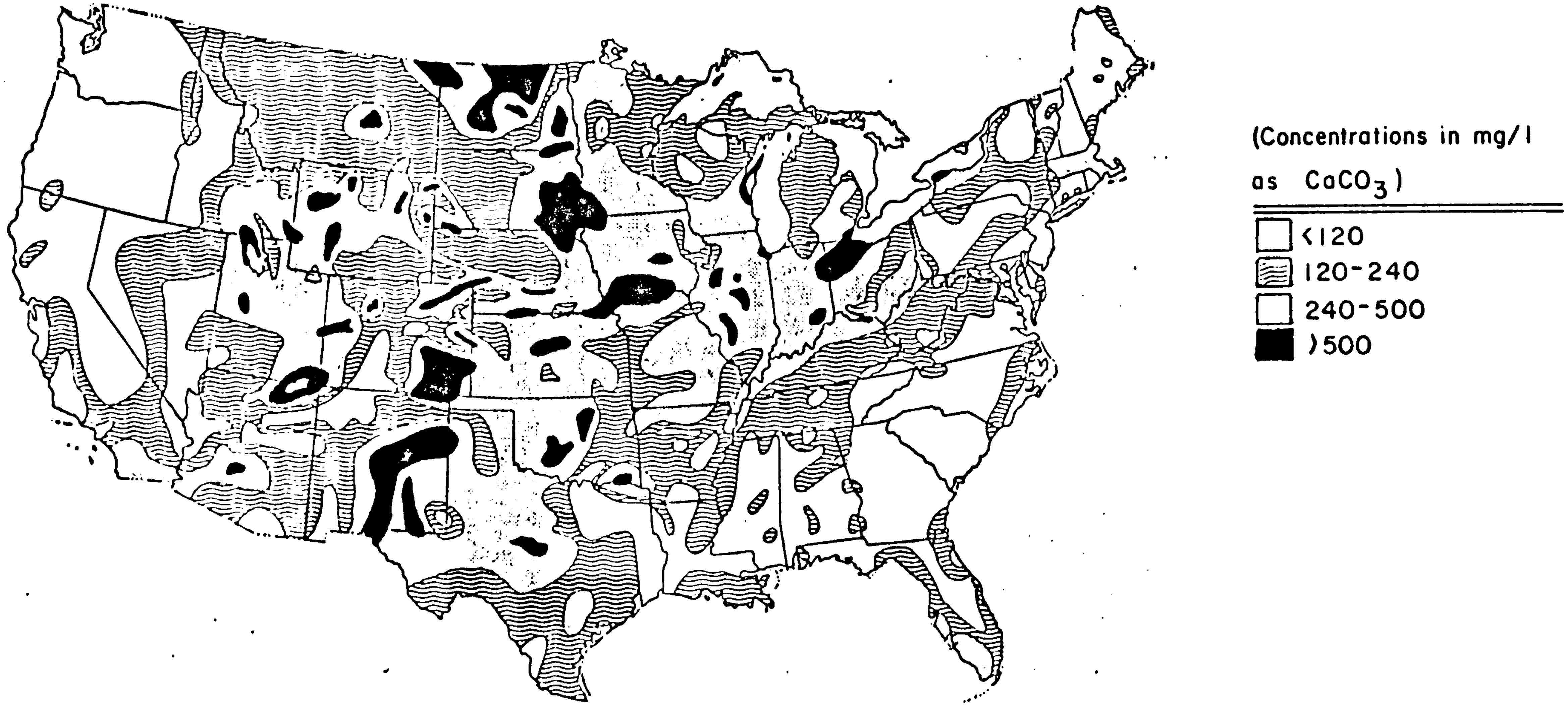


FIGURE 3 HARDNESS CHARACTERISTICS OF U.S. GROUNDWATER SUPPLIES (47)

to be the nominal life of an average water heater (48). Therefore, the expense to the home owner for water heaters in Lubbock, Texas is approximately twice as great as a result of the deteriorative effects of hard water. Another economic benefit of soft water is the decreased amounts of soap and detergent required for cleaning (21).

The most common type of unit employed for point of use water softening is a cation exchange unit which utilizes a zeolite resin. This resin must be backwashed periodically with a sodium chloride brine in order to flush accumulated suspended solids and regenerate the resin. The backwash is then discharged into the household's sewage disposal lines. If the sewage disposal lines discharge into a septic tank, the backwash will be introduced into the tank.

The effects of the introduction of softener regeneration waste into a septic tank on septic tank system performance are not fully understood. A 1949 - 1954 United States Public Health Service investigation considered both the effects of the introduction of softener regeneration wastes upon the performance of a septic tank and the effects of the application of septic tank effluent containing these wastes upon the subsurface disposal field. The study noted no adverse effects upon the performance of a full-scale operating tank. However, the septic tank used for the study had acccumulated 10.2 cubic feet of sludge prior to the first salt addition. It was stated that the results obtained may not be applicable to a septic tank having little or no sludge accumulation such as a new installation, or a tank being returned to service after cleaning without adequate seed sludge (8, 66, 67). Furthermore, the tank was dosed with simulated softener regeneration wastes once every 7 days. This interval between regeneration cycles is much longer than that of actual operating practice (55).

Regarding the effects of a high sodium and salt concentration upon the subsurface disposal field, the investigation's data indicated that percolation rates were higher with salt effluent than with normal effluent, but that soil structure was more damaged by the salt effluent. Since soil aggregate water stability is an index of sustained permeability, it was postulated that such damage may be more important from the long-time viewpoint than short-time percolation behavior (8, 66, 67).

The water softening industry purports that no harmful effects on septic tank biological action can be attributed to softener wastes (68). However, the aforementioned Public Health Service investigations with their limitations are the bases of their position. Laak and Crates

(32) state that there is an absence of conclusive data and some degree of controversy concerning the practice of backwashing water softener brine into an on-site disposal system. Warshall (64) states that waste brines from household water softeners should never be discharged into a septic tank system, as they result in soil clogging. Corey et. al. (15) found that comparison of sodium adsorption ratios and soluble salt concentrations of a number of septic effluents with calculated threshold values indicated that salts in waste waters from the regeneration of water softeners created no hydraulic conductivity problems in septic tank drainage fields, but that reduced hydraulic conductivities might result if water of low soluble salt concentration (such as rainwater) were to enter these fields. As the soluble salt concentration is lowered in a soil receiving a water high in sodium concentration, the hydraulic conductivity begins to decrease at the point the soil aggregates start to swell. Swelling decreases the average size of soil pores which lowers hydraulic conductivity. However, the "effluent" samples in Corey's study were taken from the top of the septic tank below the scum layer and may not be representative of actual effluent because of density stratifications that may occur at various depths within the tank.

Thus, further investigation of the effects of home water softener regeneration wastes on septic tank system performance is warranted. This study was undertaken with the aforementioned objective. More specifically, objectives were to determine:

1) If bacterial action is inhibited as a result of sodium chloride introduction in the tank resulting in:
    a) Decreased bacterial populations and therefore decreased degradation of settleable solids resulting in the necessity of more frequent sludge pumpings.
    b) Decreased organic stabilization.
2) If chloride concentrations within the tank become density stratified.
3) Possible effects on septic tank effluent disposal fields and on groundwater as a result of the effluent produced by a septic tank receiving water softener regeneration wastes.

Findings of this study will enhance the body of knowledge in the area of on-site disposal of domestic wastewater and are particularly applicable in West Texas where many households employ septic tanks and point of use water softening.

CHAPTER II

LITERATURE REVIEW

The following chapter is divided into six sections. The first section discusses home water softeners and the processes involved in their operations. The second section describes the characteristics and associated flow rates of domestic wastewater. The third section reviews septic tank - soil absorption systems. Elements of design, treatment processes, and problems and associated failures are also addressed in this section. The fourth section briefly explains the effects of sodium chloride on bacterial growth. The fifth section examines the effects of sodium on soils, and the sixth section reviews the effects of sodium and chloride on groundwater.

Home Water Softeners

Introduction

Home water softeners employ an ion exchange process to remove hardness from a water supply. This removal is accomplished by exchanging the hardness creating cations of magnesium and calcium for cations of sodium. The ion exchange process is employed because it is by far the simplest, least expensive, and most frequently used method available for completely softening water (30, 31). In order to understand the principles of home water softening, one must have a knowledge of cation exchange.

Cation Exchange

Introduction

Robert Gans, a German researcher, first proposed the use of sodium zeolites for cation exchange in 1905 (31). He obtained a German patent for the process in 1906. Gans' process made the first use of synthetic inorganic materials for cation exchange and was based on findings obtained with mineral zeolite exchangers. These findings had their origins in 1850 when H. S. Thompson reported his observations on the ion exchange capability of cultivated soil (20).

Process

Gans' process is still used today. He showed that the passage of water through a bed of natural or synthetic zeolite resin resulted in the replacement of calcium and magnesium ions by sodium ions. Zeolites are hydrated alumino-silicates with easily exchangeable sodium ions (3). The process may be represented by the equations

$$Na_2Ze + Ca(HCO_3)_2 \longrightarrow CaZe + 2NaHCO_3$$

$$Na_2Ze + CaCO_3 \longrightarrow CaZe + Na_2CO_3$$

$$Na_2Ze + CaSO_4 \longrightarrow CaZe + Na_2SO_4$$

$$Na_2Ze + MgCO_3 \longrightarrow MgZe + Na_2CO_3$$

in which Ze represents the zeolite (28).

Regeneration

When the zeolite's capacity for removal of calcium and magnesium ions is exhausted, the resin is treated with a concentrated sodium chloride solution which results in the conversion of the zeolite back into the sodium salt as follows:

$$CaZe + NaCl \text{ (with excess)} \longrightarrow CaCl_2 + Na_2Ze$$

$$MgZe + NaCl \text{ (with excess)} \longrightarrow MgCl_2 + Na_2Ze$$

This process is known as regeneration (28, 58). A complete regeneration cycle consists of backwash to dislodge any accumulated suspended solids, brine addition, rinse, and return to service (42).

Process Design

The principal components of automatic home water softeners include a corrosion-resistant tank which houses the zeolite resin, a salt storage tank, and a timer which regulates all cycles of operation including time and frequency of regeneration. A typical automatic home water softener is shown in Figure 4.

A softener serving a two bedroom home (occupancy of four persons) would utilize approximately 0.75 cubic feet of resin and require regeneration once every 48 hours (55). Data from the Water Quality Association (68) indicates that 0.75 cubic feet of resin requires an average salt usage of 10 pounds for regeneration. The average volume of regeneration waste per cycle is about 54 gallons with an average time of regeneration waste flow of 85 minutes. These data result in a sodium chloride concentration of 22,193 mg/l in the regeneration waste.

A - Corrosion-resistant tank
B - Resin
C - Salt Storage Tank
D - Timer

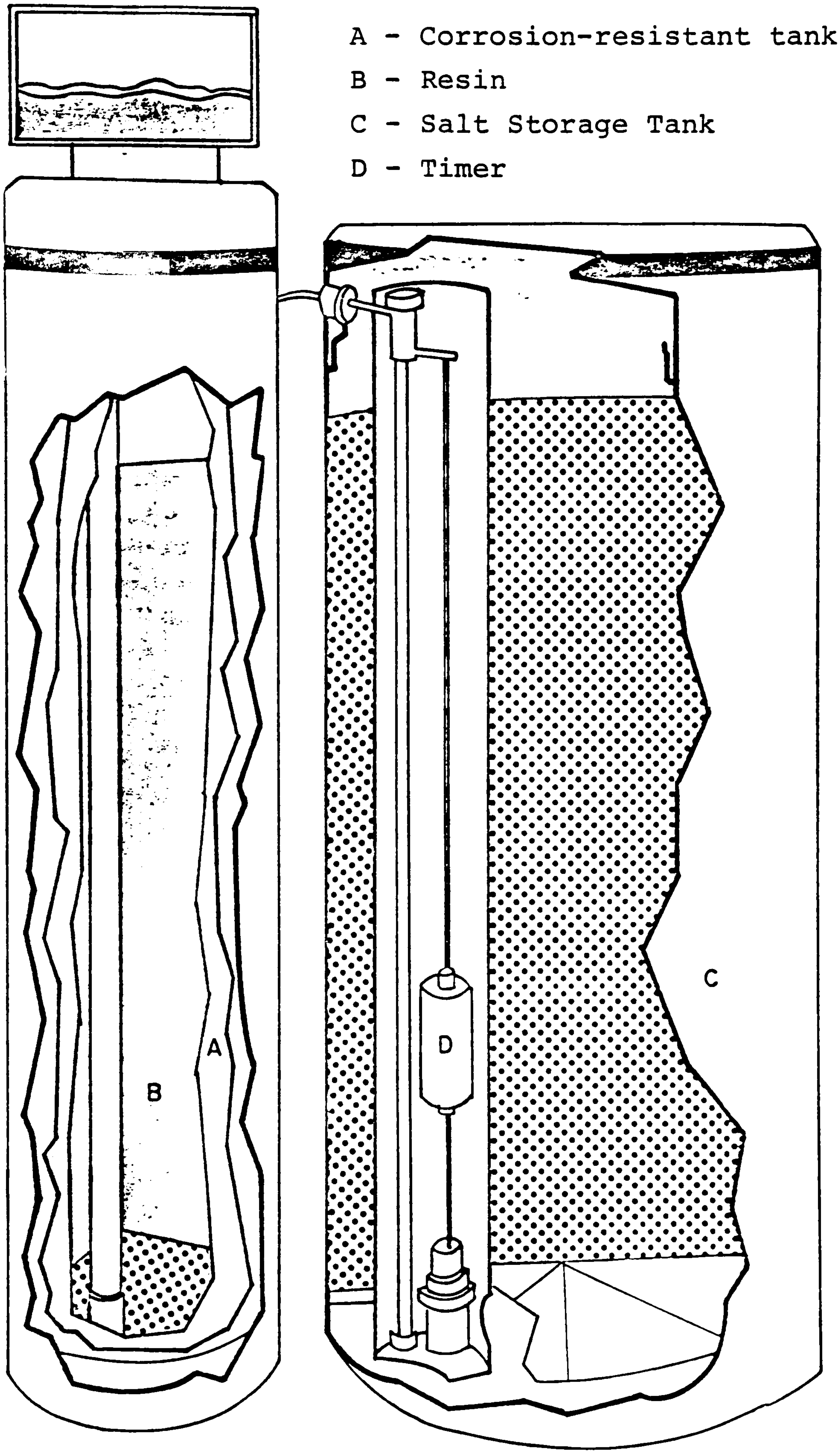


FIGURE 4 TYPICAL AUTOMATIC HOME WATER SOFTENER (17)

Domestic Wastewater

Characteristics

Domestic wastewater refers to all of the effluent produced by a household and discharged into the household's sewage lines. In order to assess the treatability of a domestic wastewater and its impact upon the treatment mode selected, one must have a knowledge of the physical, chemical, and biological constituents found therein. Table 2 shows typical compositions of untreated domestic wastewater categorized by constituent concentrations of strong, medium, and weak. It should be noted that these constituent concentrations may vary with the hour of the day, the day of the week, the month of the year, and other local conditions (39).

Flow Rates

Until recently, sources addressing the topic of domestic wastewater flow rates reported these flow rates to be approximately 50 - 100 gpcd with distinctions according to home size or economic status (i.e., small, typical, or large or average, better, or luxury (22, 39).

TABLE 2

TYPICAL COMPOSITION OF UNTREATED DOMESTIC WASTEWATER (39)

(Concentrations in mg/l)

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1200	720	350
Dissolved, total	850	500	250
Suspended, total	350	220	100
Settleable solids, mL/L	20	10	5
BOD_5, 20 C	400	220	110
Total organic carbon	290	160	80
Chemical oxygen demand	1000	500	250
Nitrogen (total as N)	85	40	20
Phosphorus (total as P)	15	8	4
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50

Source: Metcalf and Eddy, Inc. 1979. Wastewater Engineering: Treatment, Disposal, Reuse. McGraw-Hill. New York.

In recent years, several studies have been undertaken to improve the existing data base on this topic as it specifically refers to rural household wastewater flow rates. These studies characterized the total wastewater flow rate as the sum of the individual wastewater flow rates of specific events of which the primary contributors are the laundry, bathroom, and kitchen. The results of these studies showed that the average per capita flow rate ranged from 42.6 gpcd to 44.5 gpcd (9, 26, 33, 38, 53, 70). The most extensive study to date was undertaken by the University of Wisconsin Small Scale Waste Management Project (38) with a grant from the United States Environmental Protection Agency. Average daily flow patterns of eleven rural homes for a total of 434 days were characterized by individual events. An average per capita flow rate of 42.6 gpcd was obtained as shown in Figure 5. Virtually all of the wastewater flow is seen to occur during an 18 hour period.

Septic Tank - Soil Absorption Systems

Introduction

The household septic tank was patented on Septem-

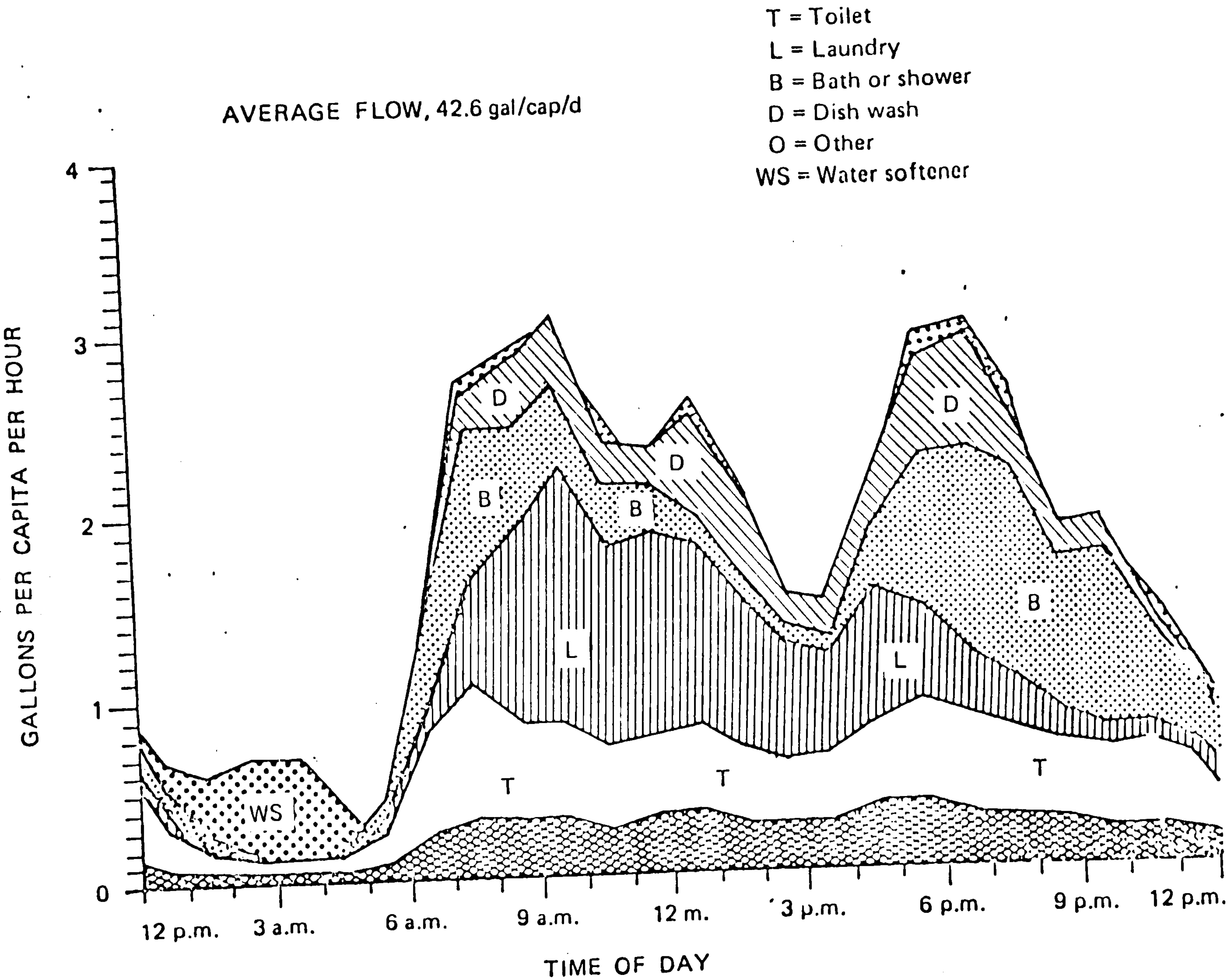


FIGURE 5 AVERAGE DOMESTIC WASTEWATER FLOW (38)

ber 2, 1881 by Jean Louis Mouras of Vesoul, France. He collaborated with a priest, Abbe Moigno, who was a scientific authority and editor of Comos les Mondes. Mouras' design is now in the public domain (67). It was called the Mouras Automatic Scavenger and was described as

> "a mysterious contrivance consisting of a vault hermetically closed by a hydraulic seal. By a mysterious operation, and one which reveals an entirely novel principle, it rapidly transforms all the excrementitious matters it receives into a homogenous fluid, only slightly turbid, and holding all the solid matter in suspension in the form of scarcely visible filaments. The vault is self emptying and continuous in its workings" (6).

This early research was related to the septic tank itself and not to the subsurface disposal field.

It was not until about 1926 that the disposal field practices were explored by Henry Ryon, a sanitary engineer working for the State of New York. Ryon devised a percolation test and correlated the soil percolation rate as measured by the test with its ability to accept septic tank effluent. From these correlations he made plots of the absorption area required per person versus the measured percolation rate (14, 45).

The general belief that a septic tank is a "self emptying and continuous process" has resulted in many failures of both the tank itself and of the subsurface disposal field. However, when properly maintained, a septic tank system provides a mode of wastewater treatment that is both low in cost and relatively free of operational problems (49).

Septic Tanks

Septic tanks provide a low energy form of wastewater pretreatment for ultimate infiltration into the soil. The primary form of treatment effected by a septic tank is gravity settling of solids. Biological treatment also occurs within a septic tank, but the effluent produced is not of sufficient quality to be directly discharged into a receiving stream because it is malodorous and still high in oxygen demand. However, with proper design and maintenance, a septic tank can yield an effluent which can be readily accepted by a soil for further treatment.

Septic Tank Design

The design of a septic tank must provide for a minimum liquid capacity, adequate scum and sludge storage, protection of the inlet and of the outlet, adequate venting for the escape of toxic and explosive gases, and access to the tank interior for inspection and cleaning.

The recommended size of a septic tank is based on estimated peak flows rather than on average per capita flows in order to ensure that the system will not fail when large or additional flows such as those resulting from guests staying in the home occur (2). The design basis recommended by the United States Public Health Service is 375 gal/d per bedroom assuming two person occupancy of each bedroom. Thus, for a two bedroom home, the recommended minimum tank capacity is 750 gallons (60). A survey of Codes indicates that states commonly mandate or recommend this minimum capacity for two bedroom homes (32).

Sewage contains from 20 - 40 mg/l of fats or grease. Since grease is lighter than water and floats, it will accumulate as a scum on the surface of the septic tank and tend to dry out and harden. Therefore, it will digest much more slowly than the solids which accumulate on the bottom of the tank. A scum clear space of approximately 4 inches should be provided in all septic tanks when the water level is at the invert of the outlet (6).

Sludge is composed of accumulated solids and settled bacterial mass. The accumulation of sludge within a septic tank can be estimated as follows:

$$S = 7.5\,t + 17 \qquad (67)$$

where S = sludge in gal/capita

t = years after cleaning

Hence, in one year, a septic tank serving a two bedroom home (occupancy of four persons) would accumulate approximately 98 gallons of sludge. This figure compares to a value of 98.3 gallons which can be determined quantitatively on the basis of volatile suspended solids content of domestic wastewater following the method of Baumann et. al. (6). Approximately two-thirds of the liquid volume of the tank should be reserved for sludge storage (16).

The inlet of a septic tank should be designed to dissipate the energy of the influent and to prevent short circuiting of the fluid moving from the inlet to the outlet. The outlet of a septic tank should be designed to prevent the effluent from containing any sludge, scum, or flotable materials. Tees or baffles are usually provided to achieve these purposes. The invert of the outlet should be at least 3 inches below the invert of the inlet (56).

Figure 6 shows essential components of a septic tank including provisions for gas ventilation and access.

Tanks may be constructed of a variety of materials such as concrete, coated metal, vitrified clay, heavy-weight concrete blocks, or hard burned bricks (60). Fiber glass has also become a widely used material (22). Figure 7 shows several typical geometric configurations of septic tanks.

Septic Tank Maintenance

When considering a 750 gallon septic tank, an annual sludge accumulation of 98 gallons would occupy 13% of the tank volume. In three years, over 40% of the tank volume would be occupied by sludge necessitating pumping of the tank so as not to interfere with the storage volume required for the removal and retention of settleable solids. On this basis, many investigators recommend sludge pumping at least once every three years (1, 6, 16, 32, 39, 61, 64). The United States Public Health Service recommends that the tank be inspected at

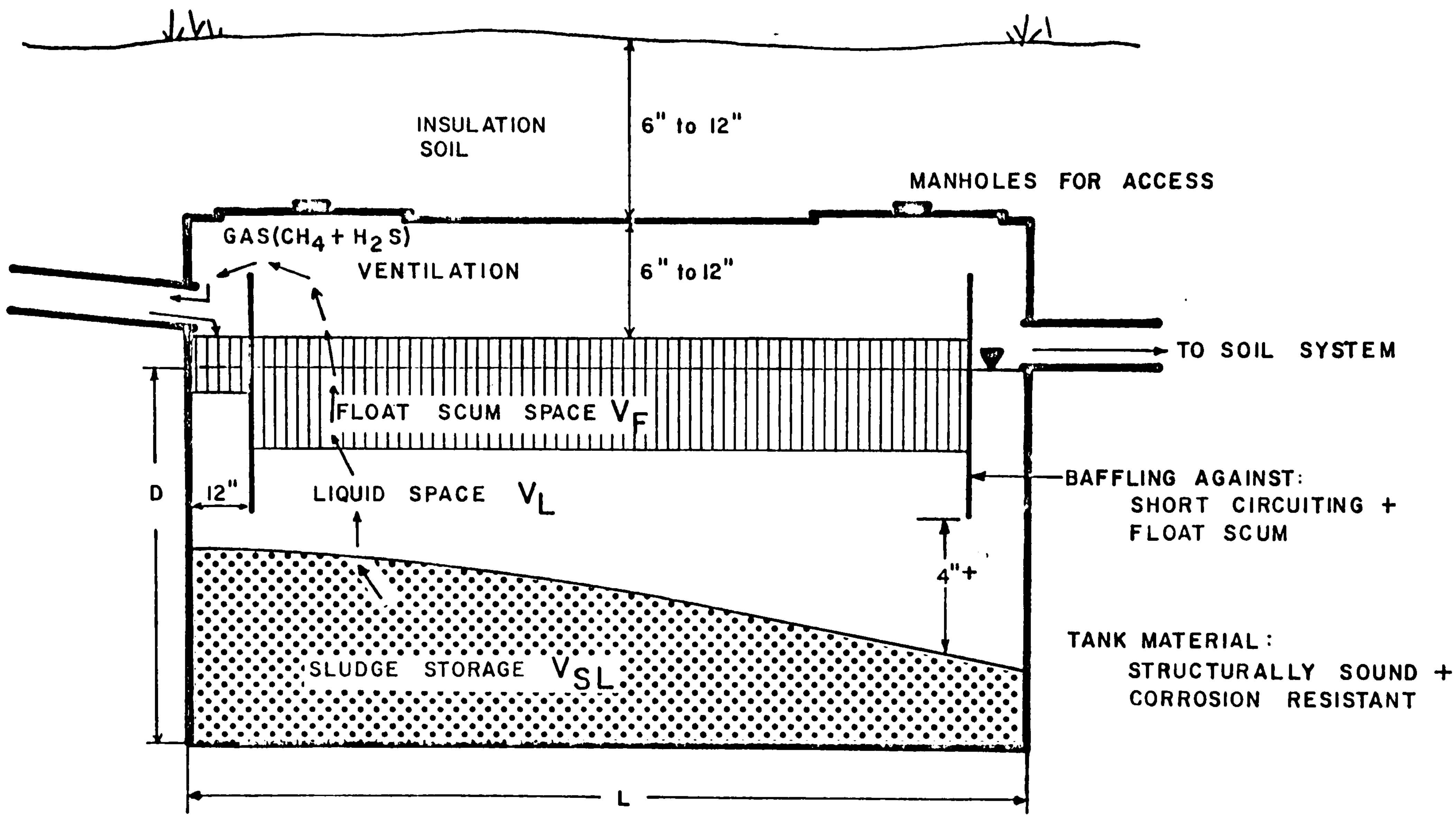


FIGURE 6 ESSENTIAL COMPONENTS OF A SEPTIC TANK (32)

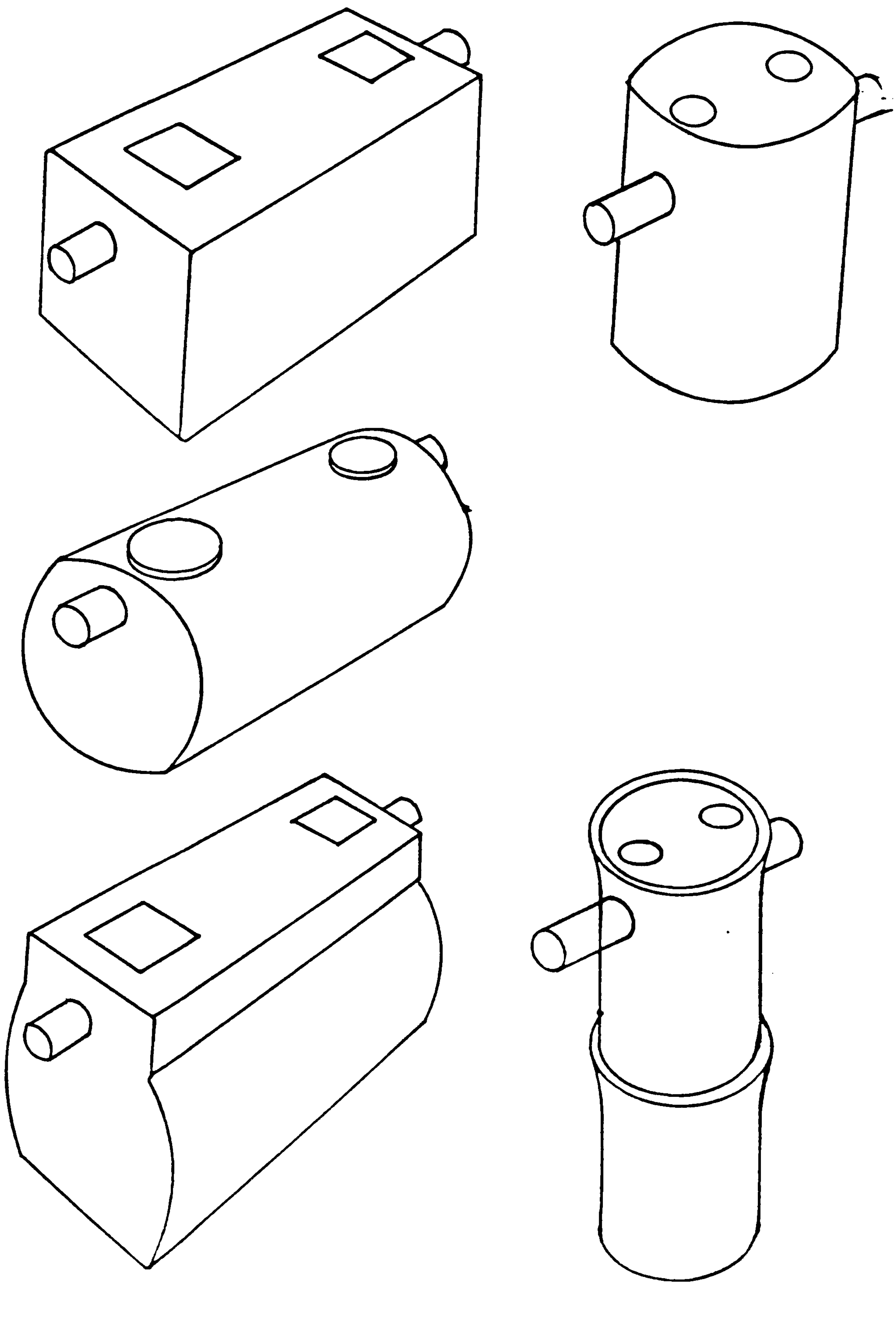


FIGURE 7 TYPICAL SEPTIC TANK SHAPES (60)

least once a year and cleaned when either (a) the bottom of the scum mat is within approximately three inches of the bottom of the outlet device; or (b) sludge comes within the limits shown in Table 3 (60).

Septic Tank Treatment and Performance

A septic tank provides an oxygen-starved environment that allows anaerobic bacteria to digest solids within the tank. Therefore, a septic tank behaves as an anaerobic reactor (41).

The approximate efficiency of an anaerobic reactor process is shown in Figure 8. The efficiency of septic tank treatment processes may be expressed as follows:

a) $BOD_e = 4\ (BOD_i)^{2/3}$ — subscripts define -
e - effluent
i - influent

b) $SS_e = 2.5\ (SS_i)^{2/3}$ — SS - suspended solids (mg/l)

c) Total nitrogen 10 to 15 g/c/d is reduced by 10% via storage in the sludge.

d) Phosphate 2 to 6 g/c/d is reduced by 20% to 30% via storage in the sludge.

e) Coliform organisms are mostly non-pathogenic and are not significantly removed. Pathogenic organisms are usually not excreted by healthy people. The removal of pathogens has not been significantly studied (32).

A review of the literature indicates that several

TABLE 3

ALLOWABLE SLUDGE ACCUMULATION (60)

Liquid capacity of tank, gallons	Liquid Depth 2.5'	3'	4'	5'
	Distance from bottom of outlet device to top of sludge, inches			
750	5	6	10	13
900	4	4	7	10
1000	4	4	6	8

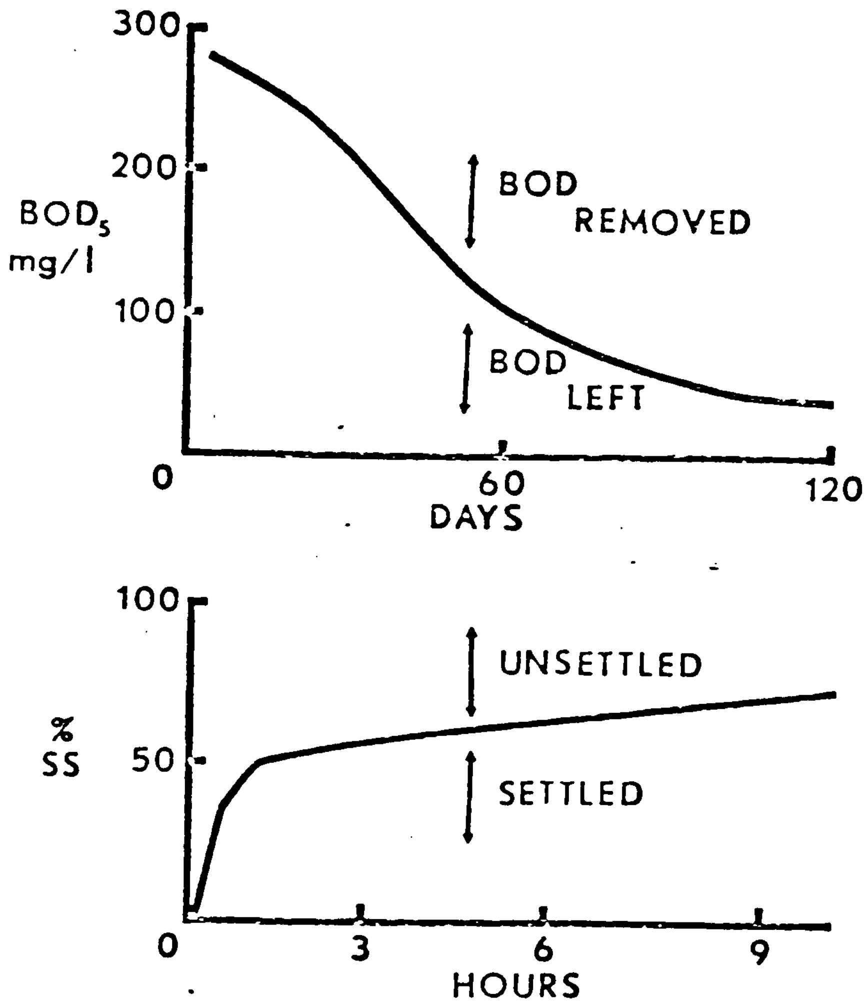


FIGURE 8 ANAEROBIC REACTOR TREATMENT EFFICIENCIES (32)

SOURCE: Laak, R. and Crates, F. J. 1978. "Sewage Treatment by a Septic Tank." Proceedings of the Second National Home Sewage Treatment Symposium. American Society of Agricultural Engineers. St. Joseph, Michigan.

investigators have studied septic tank performance (5, 6, 16, 43, 62). Parameters frequently examined have included solids retention and biological treatment. A septic tank should retain almost 100% of the settleable solids it receives (6, 32, 49). The effluent from a septic tank contains approximately 20% to 40% of the suspended solids of the influent (6, 39). A well-designed septic tank should remove 65% to 80% of the influent BOD_5 (6).

Otis and Boyle (43) studied the performance of eight treatment systems in field installations, six of which were septic tanks. Of the septic tanks, three of the six received water softener regeneration wastes. Although family size, average daily flow, household appurtenances, etc. differed from installation to installation, a comparison of the results reveals that the septic tanks receiving water softener regeneration wastes had higher effluent filtered COD concentrations than the other septic tanks. Hence, it can be concluded that the addition of water softener regeneration wastes to three of the septic tanks of Otis and Boyle's study resulted in reduced treatment efficiencies.

Soil Absorption Fields

Introduction

The clarified effluent from a septic tank is ultimately treated by percolation through a soil absorption field. In order to assess the suitability of a particular location for a soil absorption field, site selection and design criteria must be examined. Once it is in operation, the field's treatment processes are dependent upon properties of the effluent itself and upon properties of the particular soil. Problems and failures associated with soil absorption fields are many, but with proper design and maintenance, many of the problems and failures may be alleviated, if not eliminated.

Site Selection and Design

Area and soil characteristics must be examined in order to assess the suitability of a soil absorption field for a particular installation. The absorption area required may be determined on the basis of the number of bedrooms to be served as shown in Figure 9. A safe distance between the site and any source of water supply must be maintained in order to minimize

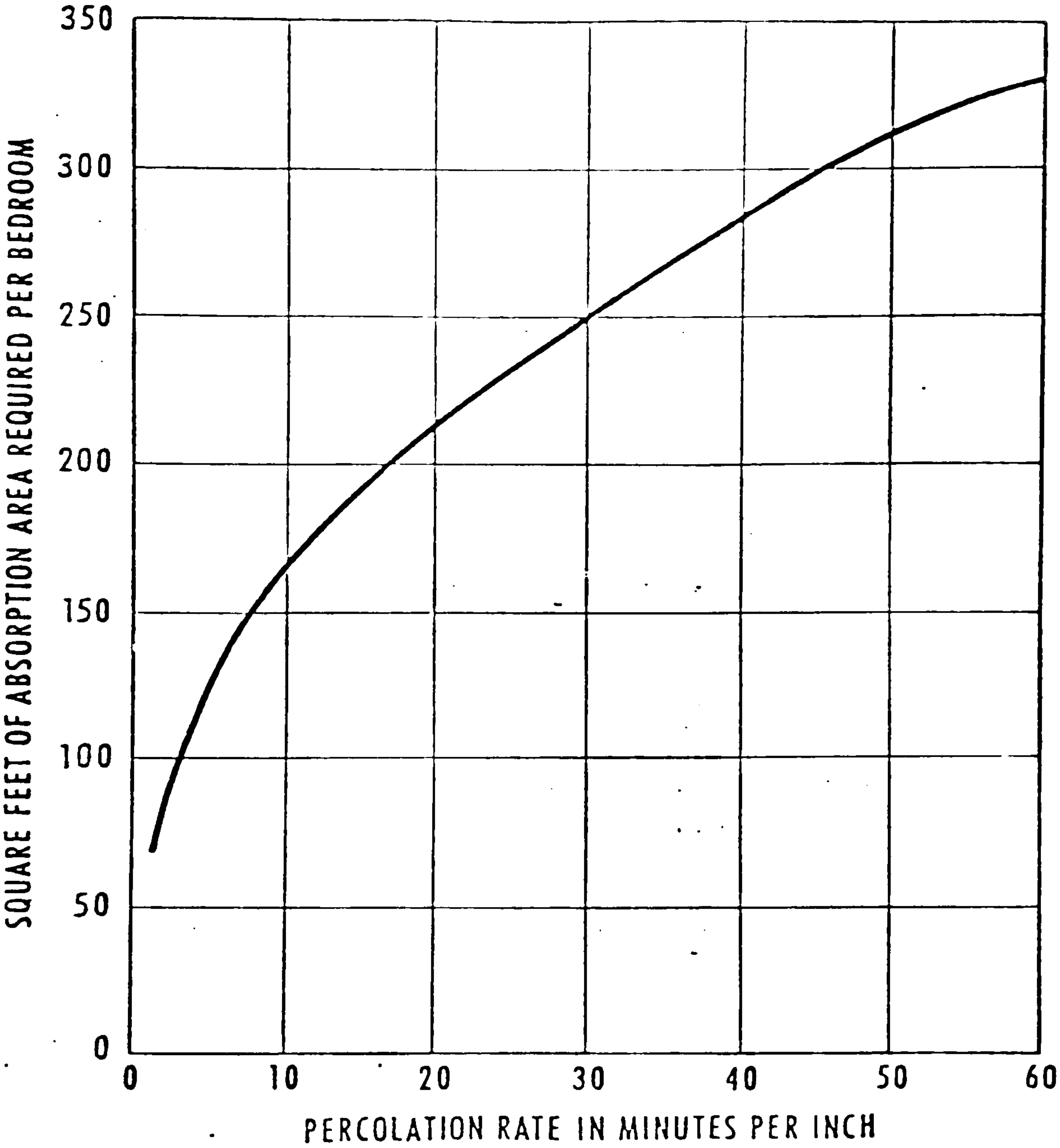


FIGURE 9 ABSORPTION AREA REQUIREMENTS FOR PRIVATE RESIDENCES (60)

health hazards. The minimum distance between components of a soil absorption system and local features should be as shown in Table 4. Potential groundwater contamination should be minimized as well. The maximum seasonal elevation of the groundwater should be at least four feet below the bottom of the absorption trenches. Impervious strata such as rock formations should also be a minimum of four feet below the absorption trenches (60).

The soil must have an acceptable percolation rate. The only means of quantitative determination of the percolation rate is the percolation test, first devised by Ryon and since corrected by Winneberger (69) and others. However, estimates of soil absorption potential may be made based on soil maps, properties such as texture, structure, color, depth or thickness of permeable strata and swelling characteristics (60). A comparison of soil types for sand, fine sand, sandy loam, silty clay, and clay yields percolation rates in descending order of magnitude (24). An optimal site for a soil absorption field is one with a percolation rate greater than zero but less than 24 min/cm (60 min/in) with a vertical separation between the ground surface and high groundwater table or bedrock of 1.5 to 1.8 m (5 to 6 feet) (45).

The soil absorption field itself normally consists

TABLE 4

MINIMUM DISTANCE BETWEEN COMPONENTS OF SEWAGE DISPOSAL SYSTEM (60)

Component of System	Horizontal distance (feet)				
	Well or suction line	Water supply line (pressure)	Stream	Dwelling	Property line
Septic Tank	50	10	50	5	10
Disposal field	100	25	50	20	5

of a field of 12 inch lengths of four inch agricultural drain tile, two to three foot lengths of vitrified clay sewer pipe, or perforated, nonmetallic pipe. The individual laterals preferably should not be over 100 feet long, and the trench bottom and tile distribution lines should be level. The actual layout of the field depends on the size and shape of the available area, the capacity required, and the topography of the disposal area (60). A typical layout of absorption trenches is shown in Figure 10.

Treatment Processes

The proper treatment of wastewater requires about 90 cm (3 ft) of unsaturated soil (10). The soil must be unsaturated as opposed to saturated as the latter case results in a high degree of hydrodynamic dispersion (4). Therefore, a saturated soil will not adequately purify a wastewater since the degree of purification achieved is dependent upon the length of time that the wastewater and the soil particles are in contact with one another.

Unsaturated flow is established by the formation of a biological layer or mat at the infiltrative surface. This mat is called the crust or clogging zone (58).

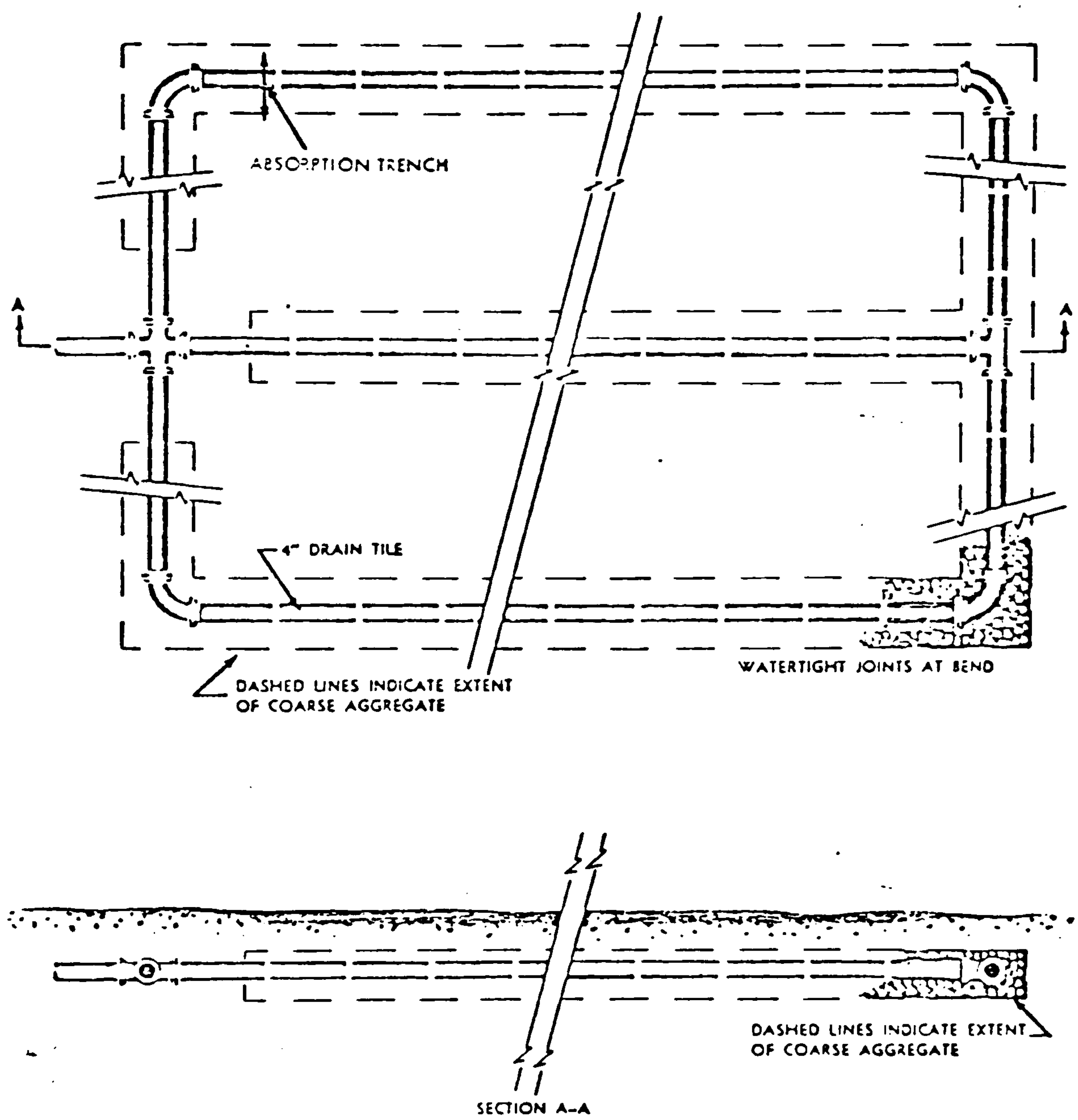


FIGURE 10 TYPICAL SOIL ABSORPTION FIELD TRENCH LAYOUT (60)

Approximately 2 to 5 cm (1 to 2 in) thick, the clogging zone is formed as a result of the slimy secretions of soil bacteria consisting of polysaccharides, mucoproteins, and other waste products. These slimy secretions trap additional bacteria and suspended solids forming a black, jelly-like mat (23).

Once the clogging zone has been established, unsaturated flow will persist in the soil. In this flow phenomenon, gravitational potential pulls water downward, and matric potential attracts water in all directions. The rate of flow increases as the potential difference of potential gradient between points increases. The ratio of the flow rate to the potential gradient is termed hydraulic conductivity. Characteristics of hydraulic conductivity are largely controlled by the geometry of the soil pores. Under conditions of unsaturated flow, soils with acceptable hydraulic conductivities exhibit improved filtration, biochemical degradation, and chemical retention of waste constituents since wastewater will be forced into the smaller pores providing closer and longer soil-liquid contact (44).

As long as the soil maintains an aerobic environment, soil bacteria which are capable of oxidatively biodegrading the organics of septic tank effluents will flourish. These bacteria can biodegrade such organics as proteins, fats, carbohydrates including cellulose of kitchen and toilet tissues, pectin and lignin of vegetable wastes and hydrocarbons (58).

By the time a septic tank effluent reaches approximately a 0.9 m (3 ft) depth below the bottoms of absorption trenches, all biochemical oxygen demand, all suspended solids, all fecal bacteria, and all viruses should have been removed provided that the soil is not overloaded (23). Brown et. al. identified nitrate leachate as the greatest environmental hazard in their study. When the soil was allowed to become oxidized, large amounts of nitrogen were converted to nitrate which rapidly leached to the groundwater.

Another process which occurs is that of cation exchange. Soil particles are negatively charged and act as cation exchangers. The first experiment that demonstrated cation exchange in soils was made in England in 1845 by H. S. Thompson, a farmer, with the help of J. Spencer, an analyst (52). Since then, much more information has been gathered concerning the cation exchange process in soils and will be discussed in a later section.

Problems and Failures of Soil Absorption Fields

Although the presence of a 2 to 5 cm thick zone of clogging is desirable to ensure conditions of unsaturated flow, serious complications arise when the soil interface becomes completely clogged or encrusted. If this condition occurs, the septic tank effluent will not infiltrate the soil properly, if at all. Thus, the effluent will "back up" appearing either on the ground surface or in the drains and toilets of the building served by the septic tank - soil absorption system. Both of these conditions constitute a nuisance and a health hazard (37).

Severe clogging and associated loss of infiltrative capacity may be the result of physical, chemical, and biological factors (27). Physical factors which result in clogging include compaction of soils by ponded water or equipment, smearing of soil surfaces by excavating equipment, and physical movement of soil fines into the voids of the infiltrative surface.

The most important chemical factor contributing to loss of infiltrative capacity is the deflocculation of soils which results in decreased permeability as a result of the introduction of high sodium waters (12). Not all soils are deflocculated to the same degree.

Those containing clay are the most affected (36).

The importance of sodium as a factor in soil clogging varies from community to community depending upon the nature of the water supply. However, a hard water softened by ion exchange could be expected to have an important effect when discharged through a percolation system. Pertinent studies concerning this topic have already been discussed in Chapter I.

Biological factors present the most significant deterrent to the proper functioning of a soil absorption field. Continuous inundation can create a severly clogged field incapable of adequate performance. If a rigorous program of septic tank inspection and sludge pumping is not maintained, solids may spill out of the tank and further clog the disposal field. Both continuous inundation and spillage of solids from a septic tank can result in an intensification of the clogging zone at the soil interface as a result of the increased slime growth of large populations of anaerobic bacteria and by the deposition of ferrous sulfates (16).

Maintenance

Preventative maintenance of a soil absorption field is related to adequate septic tank maintenance (i.e., frequent sludge pumpings) as was shown above. Harkin et. al. (24) found that the addition of small amounts of hydrogen peroxide (approximately 5 gallons) at the time of septic tank pumping could destroy any incipient crust forming in the field. If sufficient area is available, the alternating use of two absorption fields can prevent overloading and resulting failures. It has been shown that resting a drainfield for a period of several months can restore adequate operating performance (16).

Recovery of completely failed systems can be readily achieved through the addition of 15 to 40 gallons of commercial 50% hydrogen peroxide diluted simultaneously with the application of 300 to 400 gallons of fresh water. However, it is first necessary to pump out the stagnant water which the field will have accumulated (24).

Effects of Sodium Chloride on Bacterial Growth

In general, salts have two effects on bacterial growth. In very low concentrations, they markedly stimulate growth and at higher concentrations they become toxic. The particular concentrations at which these effects are apparent depend upon the degree of dissociation of the salt, the nature of the anion, the valency, and the molecular weight of the metallic ion (13).

Microorganisms which can tolerate high salt concentrations are halophiles. However, the anaerobic bacteria present in a septic tank are non-halophiles and exhibit an increasing inhibition of growth with increasing sodium chloride concentrations after an optimum concentration of 0.05 N. Growth inhibition is a result of the increased concentrations of sodium chloride acting as osmotica allowing the survival of only isolated protoplasts (57).

Sodium chloride concentrations greater than 1 N result in a complete inhibition of growth (57). Plasmolysis, a contraction of the cell protoplasm, may be the cause of complete growth inhibition at high concentrations. If the cell is impermeable to the solute, increased osmotic pressure may withdraw water from the cell, concentrate its internal solutes and induce plasmolysis (25).

Effects of Sodium on Soils

The deleterious effects of sodium on the performance of a soil absorption field have been discussed. In order to assess the effects of sodium on other soil uses such as plant growth, one must have an understanding of the cation exchange capacity, sodium adsorption ratio, and the specific conductance.

Cation exchange capacity is one of the most important properties of soil. It can be measured quantitatively and is closely related to the physical and chemical behavior of soil. If the cation exchange capacity of a soil is known, the grams of any particular cation that it can adsorb may be calculated as follows:

$$\text{grams adsorbed per 100 g of soil} = \text{meq per 100 g} \times \frac{\text{atomic weight of cation}}{\text{valence of cation} \times 1000} \qquad (18)$$

The cation exchange capacity of a soil as it relates to sodium is significant since sodium is the least retentatively held of all the exchangeable cations in soils (52). Some minerals have greater charges than others and can contribute greatly to variations in the exchange capacity (58).

Two other parameters of significance in the assessment of the effects of sodium on soils are the sodium adsorption ratio (SAR) and the specific conductance. Water with a high SAR can render the soil impermeable to air and water. When such soils become wet, they become plastic and sticky. The formula used to compute

SAR is

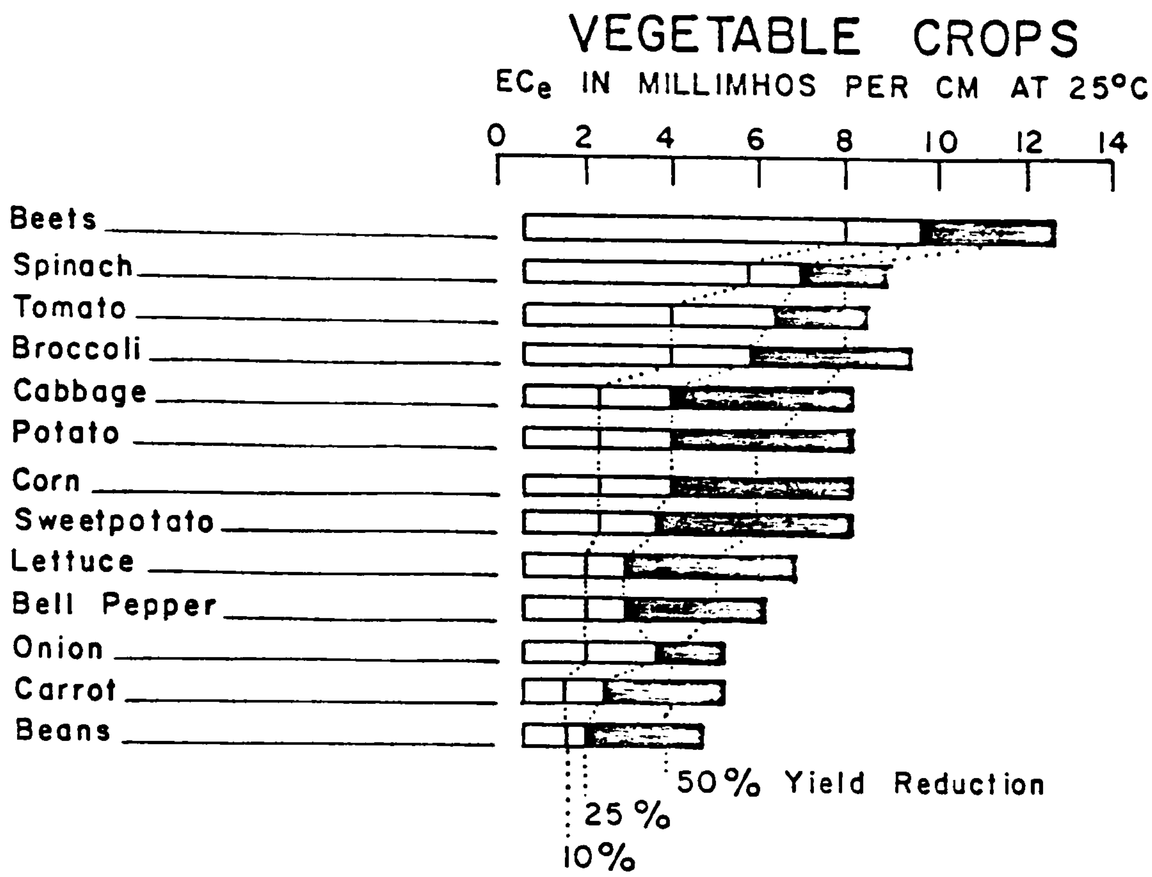
$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad (35)$$

where the concentrations are expressed in equivalents per million. A value of SAR = 8 is considered satisfactory, 12 to 15 is marginal, and more than 20 is serious. The high SAR values require special management practices such as the application of gypsum or the treatment of the soil with acid to release calcium from insoluble lime. However, in order to properly assess the effects of a SAR value, the specific conductance must be determined since the higher the specific conductance, the more sodium can be tolerated.

Specific conductance is expressed in millimhos per centimeter (mmhos/cm) at 25°C where the average relationship between specific conductance and salt concentration is: 1 mmho/cm = 464 mg/l NaCl (34). Figure 11 shows salt tolerances of crops as a function of specific conductance.

Effects of Sodium and Chloride on Groundwater

Groundwater contamination by septic tank - soil absorption systems is an issue of major concern since half of the population of the United States obtains



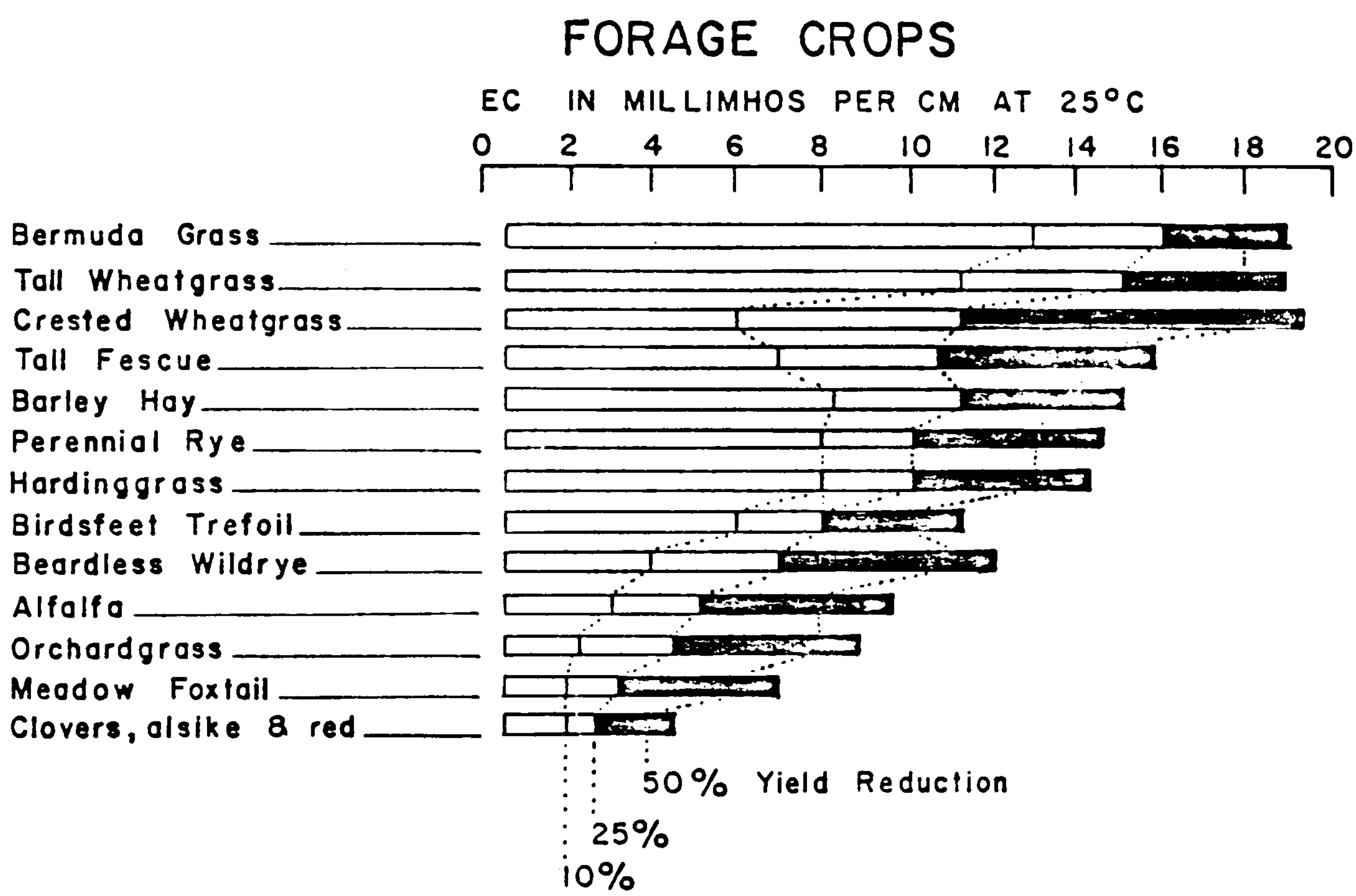


FIGURE 11 CROP YIELD REDUCTION AS A FUNCTION OF SPECIFIC CONDUCTANCE (35)

SOURCE: McGauhey, P.H. 1968. Engineering Management of Water Quality. McGraw-Hill. New York.

its water supply from groundwater sources (40). Groundwater contamination is the degradation of the natural quality of groundwater as a result of man's activities. Once groundwater has been contaminated, the restoration of quality and the removal of pollutants by mixing with and leaching by clean groundwater is a very slow and sometimes impossible process (7).

Although there are many contaminants of importance (i.e., pathogens, viruses, nitrates, phosphates, etc.), this discussion will only address itself to the effects of sodium chloride intrusion. Both sodium and chloride can create health hazards to some individuals such as aggravated cardiovascular or renal disease (40).

A study by DeWalle and Schaff (19) demonstrated no increase in the sodium level of groundwater in the vicinity of septic tank drainfields for a period of 30 years. They attributed the constant sodium level to the ion exchange mechanism in which sodium replaces calcium in the cation exchange complex of clay. However, an increase in chloride concentration was noted.

Thus, when considering chloride and sodium, chloride presents the major threat to groundwater contamination. The chloride anion, carrying a negative charge, moves freely with water in soil since anions are much less susceptible to electrochemical adsorption than positively charged ions. Peavy and Groves (46) found that once the chloride anions reached saturated stratá, their concentration was only reduced by dilution. This finding is substantiated by the data of Viraraghavan and Warnock (63) who found significant levels of chlorides in groundwater immediately downstream from a soil absorption field, but an almost complete reduction at a distance of 50 feet.

CHAPTER III

EXPERIMENTAL PROCEDURE

Two bench-scale septic tanks were operated continuously to simulate actual operating conditions. The experimental procedure was conducted in a controlled laboratory environment at a constant temperature of 20°C. One tank served as a control (Tank 1) receiving daily synthetic sewage inputs, and a second tank (Tank 2) received both daily synthetic sewage inputs and a simulated water softener regeneration waste every 48 hours. Analyses were performed on the influent to determine the Chemical Oxygen Demand (COD). The contents of each tank were analyzed to determine the chloride ion concentration at three different heights from the bottoms of the tanks and the Mixed Liquor Suspended Solids (MLSS) concentrations. The effluent produced by each tank was analyzed to determine the filtered COD and the chloride, sodium, calcium, and magnesium concentrations.

Synthetic Sewage

Characteristics

Each tank received a daily input of synthetic sewage which was utilized rather than actual domestic sewage in order to ensure the consistency of the sewage's strength as measured by the COD analysis. The synthetic sewage was formulated to simulate the characteristics of a medium strength domestic wastewater and was based on a design by Khararjian and Sherrard (29). Quantities of compounds used in the composition of the synthetic sewage are presented in Table 5.

Flow Rates

The synthetic sewage was introduced into the tanks over an 18 hour period during each 24 hour day. This 18 hour period was shown to be the duration of virtually all domestic wastewater flows by the Small Scale Waste Management Project (38). The quantity of sewage entering each tank during this 18 hour period was based on a 42.6 gpcd value found to be the average per capita domestic flow rate by the Project. Scaling this value down to the bench-scale tanks employed in this study resulted

TABLE 5

SYNTHETIC SEWAGE CHARACTERISTICS

Stock solution and quantities used per 18 l.

Compound	Stock Solution (g/l)	Quantity Used
Powdered Milk		5.4 g
Beef Extract		3.5 - 4.0 g
$MgSO_4$	40	20 ml
$MnSO_4$	10	10 ml
$FeSO_4$	1.5	10 ml
$CaCl_2$	7.5	10 ml
KH_2PO_4	60	15 ml
$(NH_4)_2SO_4$	75	60 ml
Na_2CO_3	63.6	*
$NaHCO_3$	50.4	*

COD = 500 mg/l

* Quantities varied to maintain a neutral pH

in a value of 6.43 l/d (1.70 gal/d).

Simulated Water Softener Regeneration Waste

Characteristics

A simulated water softener regeneration waste was formulated based on available data from the Water Quality Association (68). A sodium chloride concentration of 22,193 mg/l was utilized. A stock solution was prepared from which each of the waste additions was taken. The stock solution was mixed before each use to eliminate the possibility of any density stratification of the solution.

Flow Rates

The simulated water softener regeneration waste was added to Tank 2 once every 48 hours over approximately an 85 minute period of time. A quantity of 2.04 l was used. This period of time and quantity of waste was derived from available data from the Water Quality Association (68). The addition of 2.04 l of waste over an 85 minute period of time resulted in a flow rate of 0.024 l/min.

Experimental Design

A schematic of the experimental equipment used in this research is shown in Figure 12. The equipment consisted of two large glass bottles (one containing synthetic sewage and one containing simulated water softener regeneration waste), two peristaltic pumps, two bench-scale septic tanks, and two empty carboys which served as effluent collection receptacles.

The two bench-scale septic tanks were constructed of plexiglass so that visual monitoring of color changes in the tanks and sludge and scum accumulations would be possible. During the experimental runs, the tanks were covered since a full-scale operating septic tank would not be subjected to natural or artificial lighting. Figure 13 shows a schematic of the design of each of the tanks. A baffle was installed in the mid-section of each of the tanks to prevent short-circuiting of flows from the inlet to the outlet. Total liquid capacity of each of the tanks was 7.48 gallons or approximately 1/100th of the volume of a full-scale septic tank serving a two bedroom home. A sampling portal was located in the cover of each of the tanks on the outlet side so that the contents of the tanks could be sampled when desired. Samples were obtained by removing the rubber

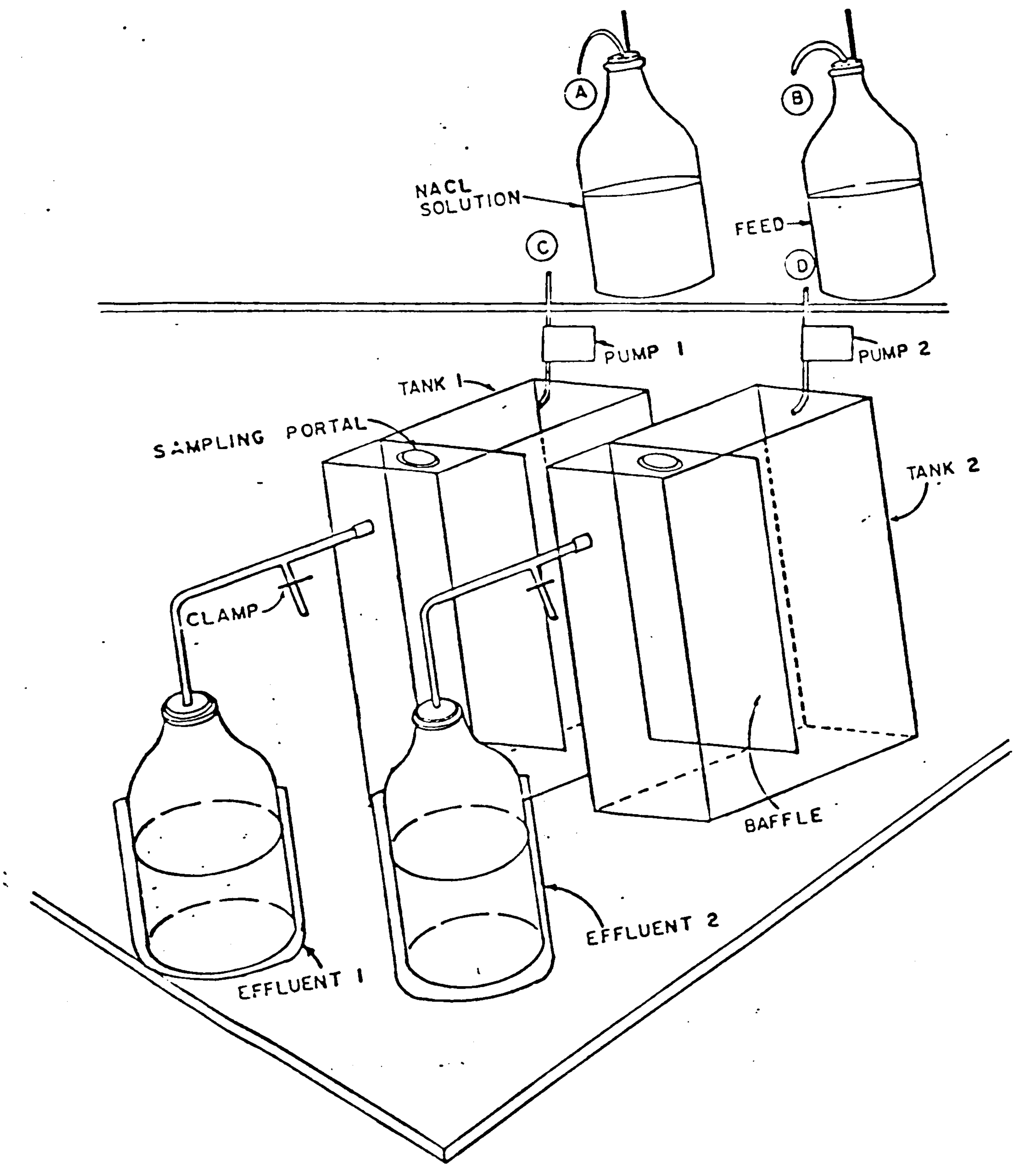


FIGURE 12 SCHEMATIC OF EXPERIMENTAL EQUIPMENT

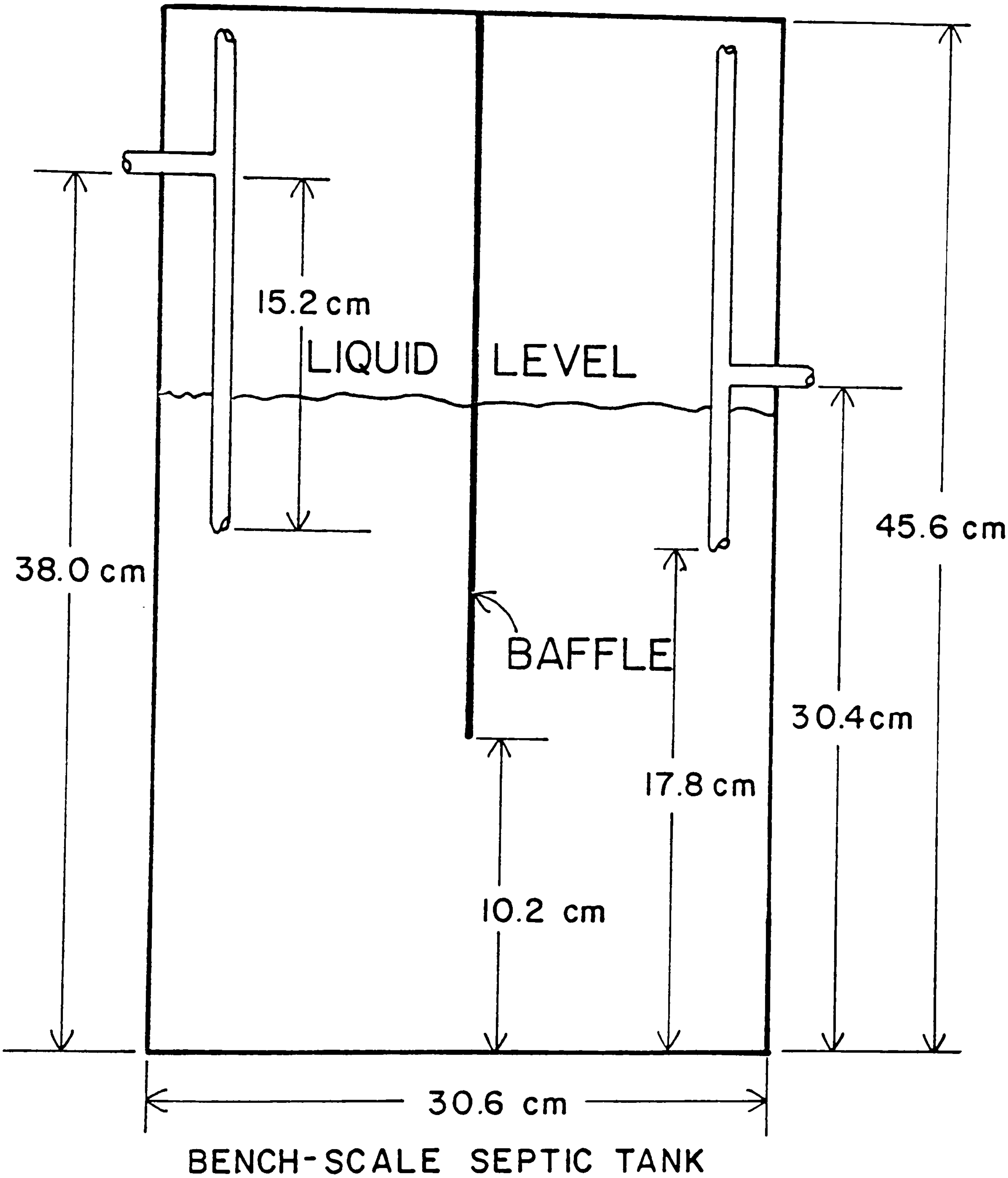


FIGURE 13 SCHEMATIC OF BENCH-SCALE SEPTIC TANK

stopper in each portal and introducing a pipet down through the hole and into the liquid contents of the tank. The outlet side of each tank was labeled with 0.5 cm gradations so that samples could be taken from the same depth each time.

Synthetic sewage was prepared daily in the glass bottle labeled "Feed" from which tubing (B) led to tubing (C) and (D). Tubing (C) and (D) led to each of two peristaltic pumps and then into each of the two tanks. The simulated water softener regeneration waste was stored in the second glass bottle labeled "NaCl solution". Tubing (A) led from the bottle to tubing (D), through a peristaltic pump and then into Tank 2.

Effluent from each of the tanks passed through tubing into each of two carboys which were emptied and cleaned daily because effluent analyses were performed on a 24 hour composite sample basis. A sampling tap was located in the tubing line between each of the tanks and its respective effluent collecting carboy for the purpose of obtaining grab samples, if required.

Chemical Oxygen Demand

Chemical Oxygen Demand (COD) analyses were made on the influent for quality control purposes to ensure the consistency of the strength of the synthetic sewage. Filtered COD analyses were made on the effluent from both tanks in order to determine the treatment efficiency of the tanks. The reflux method outlined in Standard Methods (54) was utilized.

Mixed Liquor Suspended Solids

Mixed liquor suspended solids (MLSS) analyses were performed on the contents of each tank as a means of monitoring bacterial populations. The method outlined in Standard Methods (54) for the determination of non-filterable residue was utilized.

Chlorides

Chloride levels within the tanks and in the effluents were monitored. Within the tanks, samples were taken at 5 cm, 15 cm, and 25 cm heights from the bottom of the tanks. The Argentometric (Mohr) Method as described in

Standard Methods (54) was utilized.

Sodium

The laboratory in which this research was conducted did not have the capability to perform a direct determination of sodium concentrations. Effluent samples from both tanks were analyzed at another facility and a correlation between chloride ion and sodium ion concentrations was ascertained. The ratio of the effluent chloride ion concentrations to the effluent sodium ion concentrations was compared to a theoretical ratio based on the concentrations of sodium and chloride ions in the synthetic sewage and in the simulated water softener regeneration waste as shown in Table 6. Since a good correlation existed between the theoretical and the analytical ratios, effluent sodium ion concentrations were computed on the basis of the effluent chloride ion concentrations. Therefore, the sodium concentrations reported in Chapter IV were derived mathematically and not analytically.

Specific Conductance

Specific conductances of the soluble salt concentrations in the effluent of Tank 2 contributed by the simu-

TABLE 6

COMPARISON OF THEORETICAL AND ANALYTICAL RATIOS OF CHLORIDE ION TO SODIUM ION CONCENTRATIONS

Tank	Theoretical	Analytical
1	0.44	0.44
2	1.28	1.27

lated water softener regeneration waste were computed. The sodium ion and chloride ion concentrations contributed by the synthetic sewage including the tap water contribution were subtracted from the sodium ion and chloride ion concentrations found in the effluent of Tank 2. The remaining chloride ion concentration was multiplied by 1.65 in order to determine a derived sodium chloride concentration which was then multiplied by 0.39 in order to obtain a computed sodium ion concentration. In order to determine the accuracy of this computation, the computed sodium ion concentration was compared to the actual sodium ion concentration contributed by the simulated water softener regeneration waste. Since the correlation between the two concentrations was found to be acceptable, the specific conductance was computed on the basis of 1 mmho/cm = 464 mg/l NaCl.

Calcium

Each of the effluents was analyzed for calcium concentrations. The EDTA titrimetric method as described in Standard Methods (54) was utilized.

Magnesium

Since total hardness represents the sum of the calcium and magnesium ions present in a sample, magnesium ion concentrations were determined indirectly. Total hardness analyses were performed on the effluents from both tanks, and the concentrations obtained from the calcium analyses were subtracted, yielding the values of the magnesium concentrations. The EDTA titrimetric method was utilized as presented in Standard Methods (54).

Phase Two Experimental Procedure

The first phase of experimentation consisted of daily synthetic sewage inputs to Tanks 1 and 2 and simulated water softener regeneration waste inputs every 48 hours to Tank 2. At the end of the first phase of experimentation, a second phase was initiated consisting of simulated water softener regeneration waste inputs every 48 hours to Tank 1 in addition to daily synthetic sewage inputs.

The characteristics of and flow rates associated with the simulated water softener regeneration waste are the same as those utilized in the first phase of experimentation.

Phase Two Test Procedures

The contents of Tank 1 were sampled to determine the mixed liquor suspended solids concentration and the chloride ion concentrations at three heights from the bottom of the tank as in the first phase of experimentation. The effluent of Tank 1 was analyzed to determine the filtered chemical oxygen demand and the chloride, sodium, calcium, and magnesium ion concentrations. Effluent analyses were also performed as in the first phase of experimentation.

CHAPTER IV

RESULTS AND DISCUSSION

Chemical Oxygen Demand Analyses

Presented in Figure 14 are the results of the Chemical Oxygen Demand (COD) analyses performed on the effluent from Tanks 1 (Control) and 2 (Experimental). Examination of Figure 14 reveals an overall reduction in influent COD concentrations of 69% for Tank 1; whereas, Tank 2 exhibited an overall reduction in influent COD concentrations of only 45%. However, slightly higher reductions in influent COD concentrations can be determined once a state of equilibrium was achieved in each of the tanks. After equilibrium conditions were reached, Tanks 1 and 2 exhibited reductions of 73% and 49%, respectively. Thus, the bench-scale septic tank receiving simulated water softener regeneration wastes had a lessened biological treatment efficiency as measured by reduction in influent COD concentration. This lessened efficiency is significant because the addition of 2.04 l of simulated regeneration waste every 48 hours should have tended to lower influent COD concentrations in Tank 2 as a result of dilution.

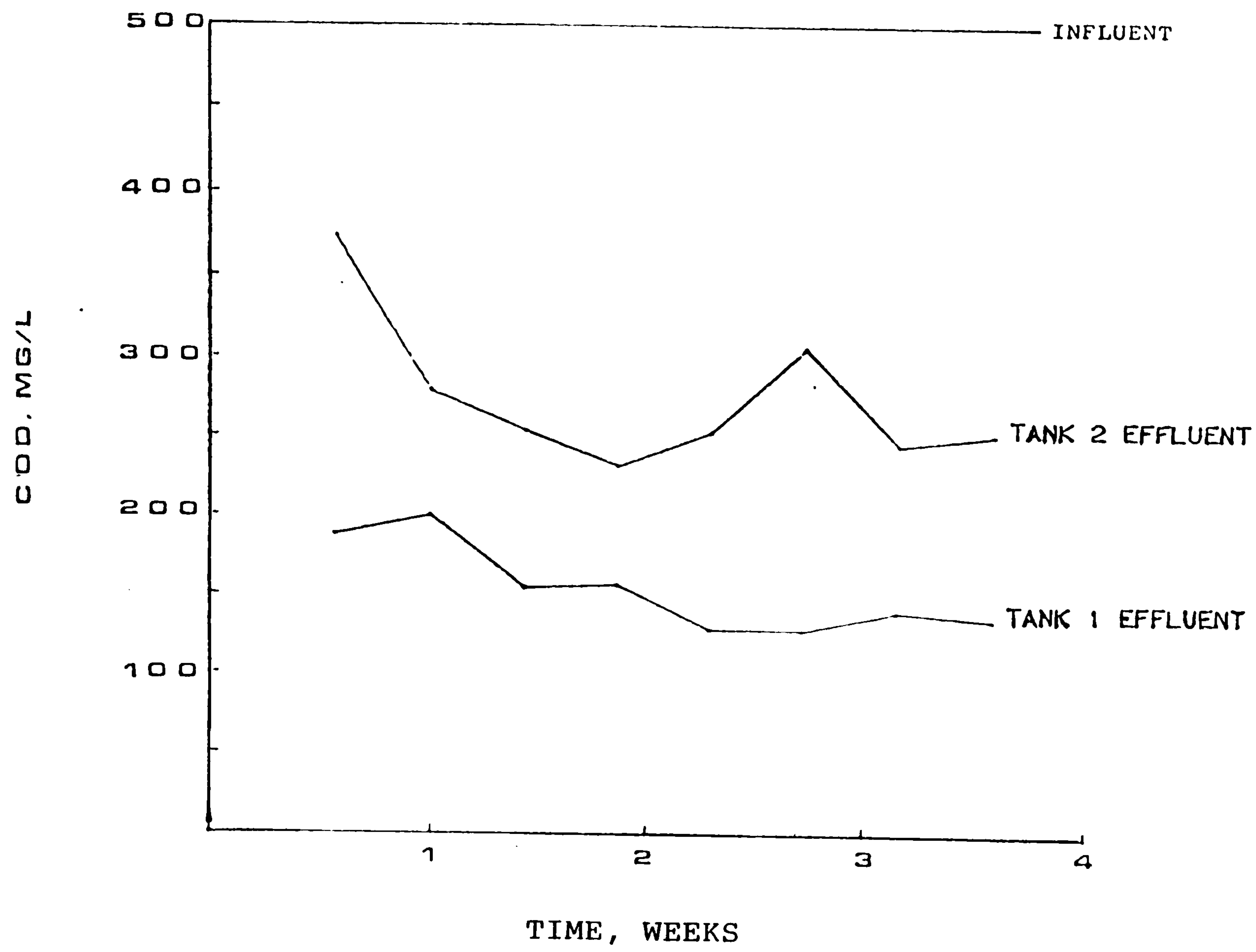


FIGURE 14 CHEMICAL OXYGEN DEMAND

Although it was determined that the treatment efficiency of Tank 2 was impaired on the basis of the effluent COD concentrations, it can be assumed that the anaerobic digestion taking place within the sludge layer of an operating tank receiving regeneration wastes would be adversely affected to a greater extent. If so, the sludge volume in such a tank might increase more rapidly than in a tank not receiving regeneration wastes. Thus, a septic tank receiving water softener regeneration wastes might require more frequent sludge pumpings.

Mixed Liquor Suspended Solids Analyses

Figure 15 shows the results of the Mixed Liquor Suspended Solids (MLSS) analyses performed on the contents of each of the bench-scale septic tanks. A comparison of the two plots reveals substantially higher MLSS concentrations in Tank 1 than in Tank 2. Therefore, it can be concluded that the bacterial population in Tank 1 was greater than that in Tank 2 since the influent to each tank contained equal but very low MLSS concentrations. This conclusion can be further substantiated by the results of the effluent COD analyses since Tank 1 exhibited a greater percentage of influent COD concentration reduction than did Tank 2.

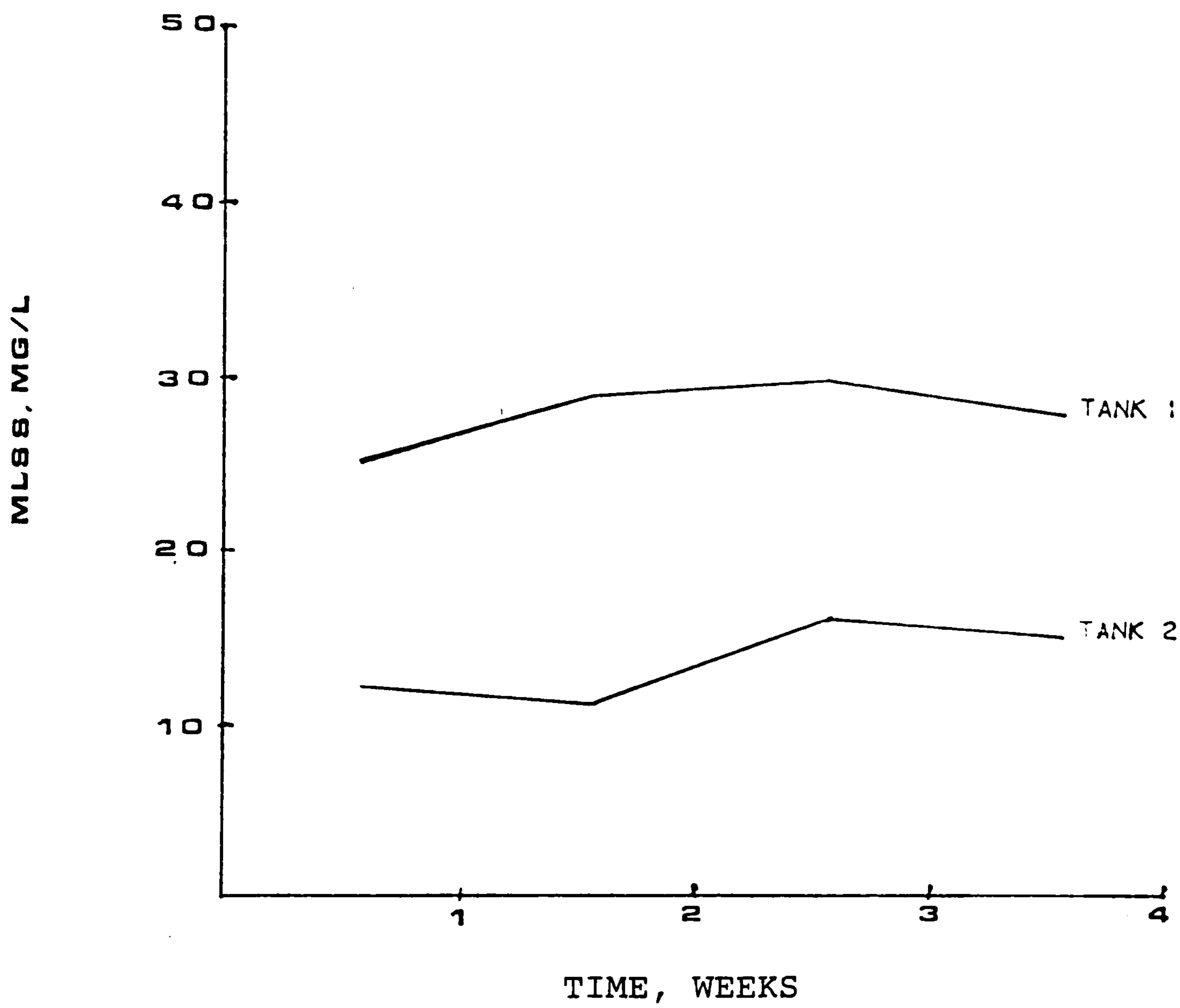


FIGURE 15 MIXED LIQUOR SUSPENDED SOLIDS

Chloride Analyses

The results of the chloride analyses performed on the contents of Tank 1 at 5 cm, 15 cm, and 25 cm heights from the bottom of the tank are shown in Figure 16. Tank 1 served as a control; therefore, no variations in chloride ion concentrations were expected nor were noted. However, examination of the chloride ion concentration results obtained at 5 cm, 15 cm, and 25 cm heights from the bottom of Tank 2, as shown in Figure 17, indicates a pattern of density stratification in Tank 2. This density stratification is a result of the concentrated sodium chloride additions which Tank 2 received in order to simulate water softener regeneration wastes. At the 25 cm height and at the 5 cm height, the chloride ion concentrations remained relatively constant throughout the experimental period; however, at the 15 cm height, the data indicated a transition period during which time the density stratification within the contents of the tank was establishing and stabilizing. Figure 18, a plot of height from the bottom of Tank 2 versus chloride ion concentration, indicates the nature of the stabilization process.

The effluent chloride ion concentrations of Tank 1 are seen to be invariant as shown in Figure 19. Further examination of Figure 19 indicates that the effluent

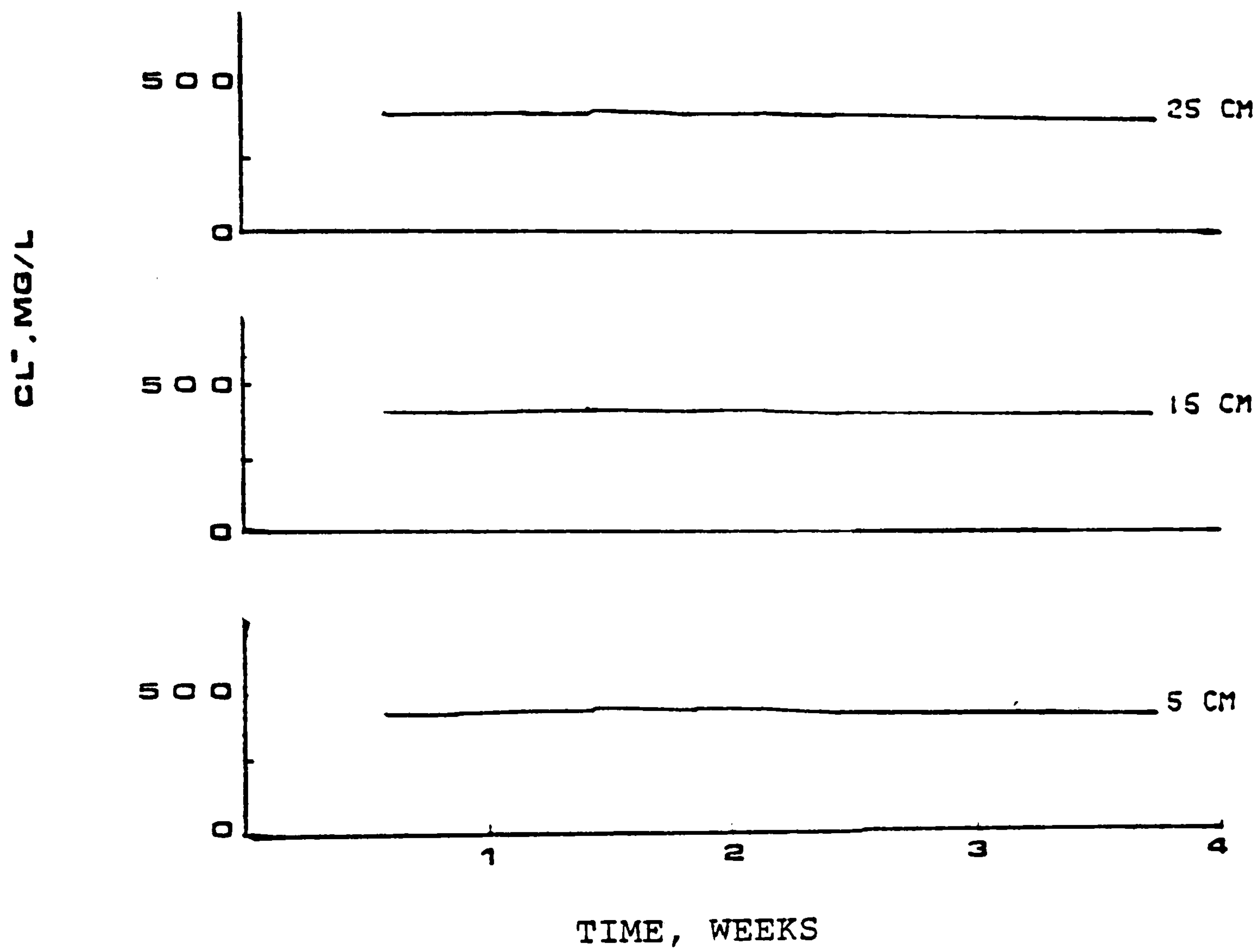


FIGURE 16 CHLORIDE ION CONCENTRATIONS, TANK 1

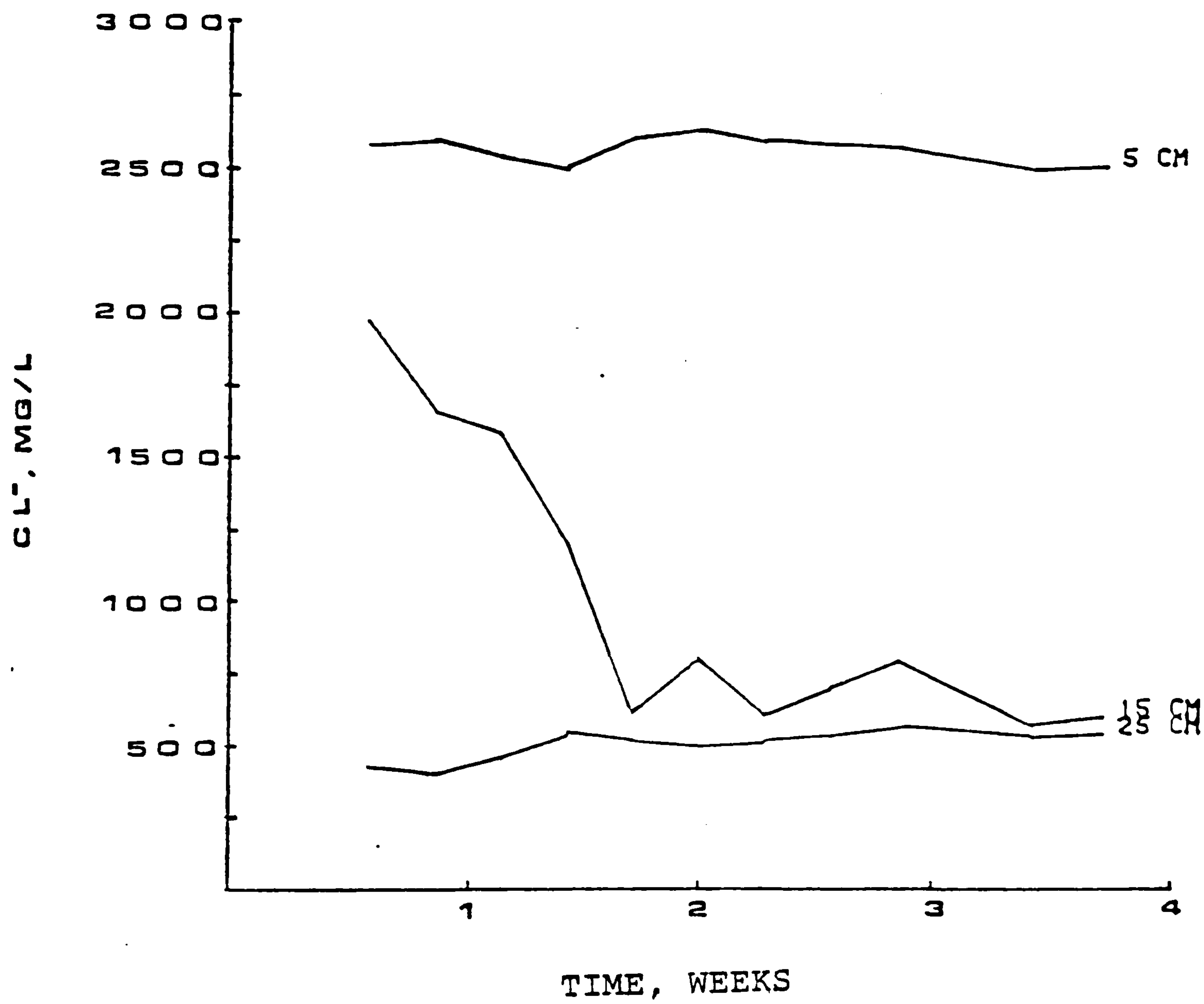


FIGURE 17 CHLORIDE ION CONCENTRATIONS, TANK 2

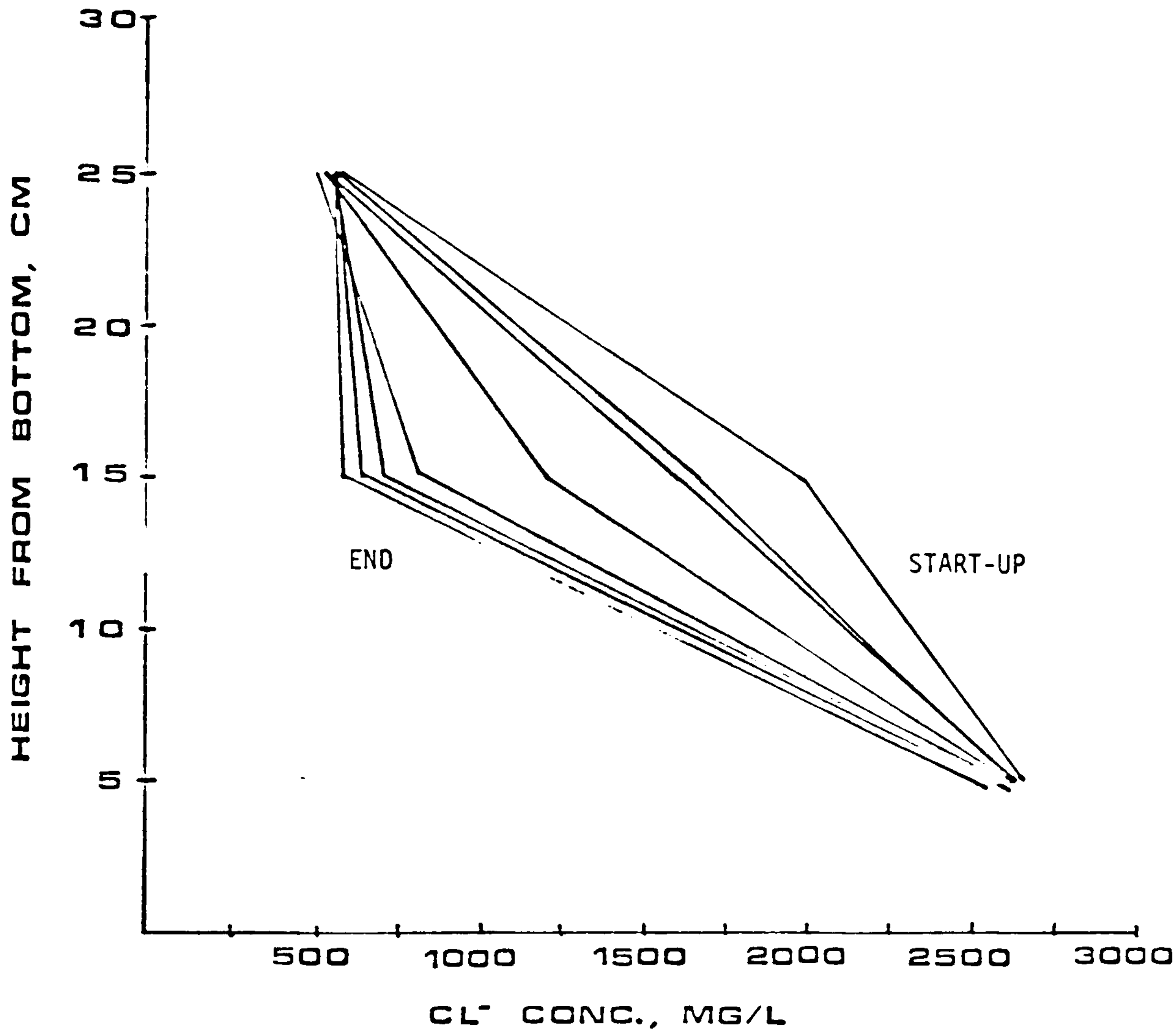


FIGURE 18 DENSITY STRATIFICATION STABILIZATION

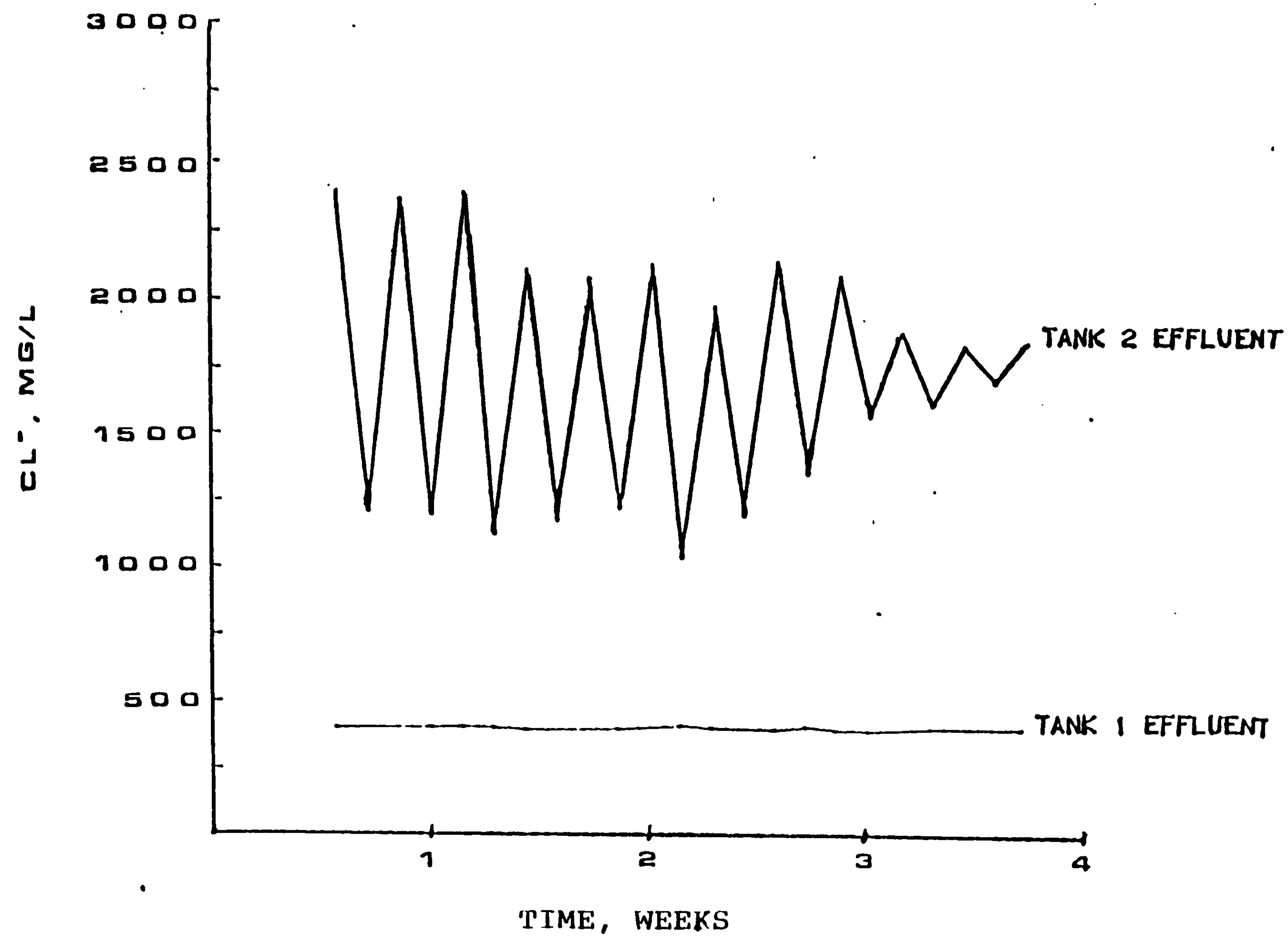


FIGURE 19 EFFLUENT CHLORIDE ION CONCENTRATIONS

chloride ion concentrations of Tank 2 are significantly higher than those of Tank 1 as a result of the simulated water softener regeneration wastes which Tank 2 received.

The significantly high chloride ion concentrations in the effluent from a septic tank receiving water softener regeneration wastes pose a threat of groundwater contamination. It is known that negative ions such as those of chloride are much less susceptible to electrochemical absorption within the soil matrix and therefore move freely with water through the soil. Therefore, once chloride ions reach the groundwater table, the only means of reduction of their concentrations is by dilution (46). Vararaghavan and Warnock (63) found that an almost total reduction was achieved at a horizontal distance of 50 feet from a soil absorption field; however, the septic tank effluent in their study had a chloride ion concentration ranging from 37 mg/l to 101 mg/l. Since the chloride ion concentrations present in the effluent of Tank 2 of this study were many times greater than those in the aforementioned study, it can be postulated that greater horizontal distances would be required for their reduction. Thus, greater minimum distances between the locations of soil absorption systems might be required in order to prevent contamination of potable water supplies.

Sodium Determination Results

The results of the sodium ion concentration determinations are shown in Figure 20. A comparison of these plots with those obtained for chloride ion concentrations in the effluents illustrates that there was a direct ratio of chloride ion concentration to sodium ion concentration.

Calcium Ion and Total Hardness Analyses and Magnesium Ion Determination Results

The calcium ion and total hardness concentrations of the effluents of Tanks 1 and 2 were constant since the addition of simulated water softener regeneration wastes to Tank 2 did not contribute any additional calcium or magnesium ions. Table 7 shows the average results of the calcium ion and total hardness analyses and the magnesium ion determination found by subtracting the average calcium ion concentration from the average total hardness concentration of the effluents of Tanks 1 and 2.

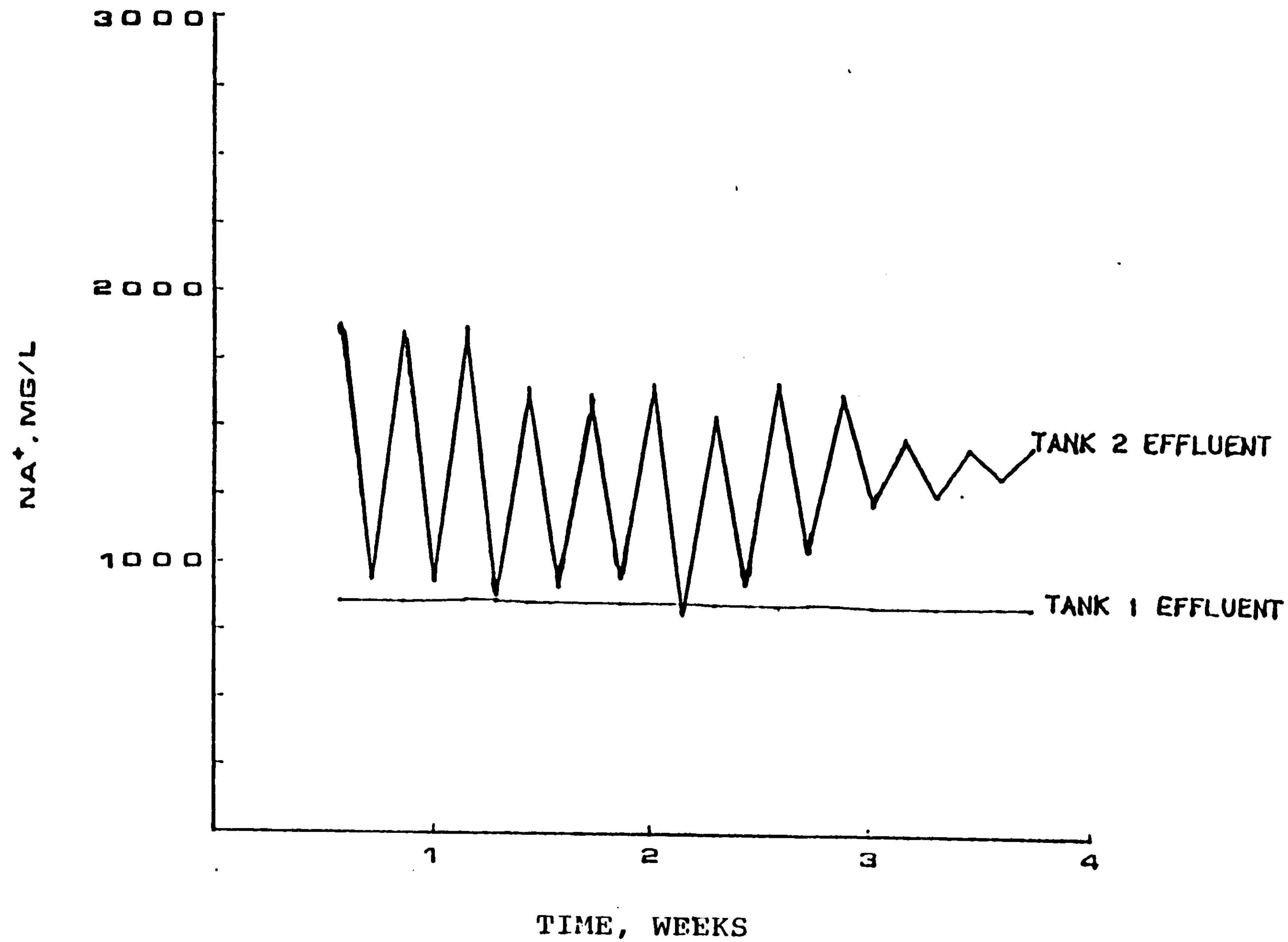


FIGURE 20 EFFLUENT SODIUM ION CONCENTRATIONS

TABLE 7

CALCIUM ION AND TOTAL HARDNESS ANALYSES AND MAGNESIUM ION DETERMINATION RESULTS

Calcium	Total Hardness	Magnesium
137 mg/l as $CaCO_3$	328 mg/l as $CaCO_3$	191 mg/l as $CaCO_3$
56 mg/l as Ca^{++}		46 mg/l as Mg^{++}

Sodium Adsorption Ratio Determination Results

The computed values for sodium adsorption ratios (SAR) of the effluent of Tank 2 are shown in Figure 21. An average value of 32 was obtained from the computations. According to the literature (35), values greater than 21 are "serious" and therefore may indicate the unsuitability of septic tank effluent containing water softener regeneration wastes for introduction into soil absorption fields. In order to completely assess the inherent sodium hazard of a water with an extremely high SAR, one must also know the value of the specific conductance.

Specific Conductance Determination Results

Figure 22 shows the specific conductance values computed for the effluent of Tank 2 on the basis of soluble sodium chloride concentrations contributed by the simulated water softener regeneration waste. An average value of 4.77 mmhos/cm was obtained. This value may be conservative since only the chloride and sodium ion concentrations contributed by the regeneration waste were used in the computations.

A water with an average SAR of 32 and a specific conductance of 4.77 mmhos/cm has a very high sodium

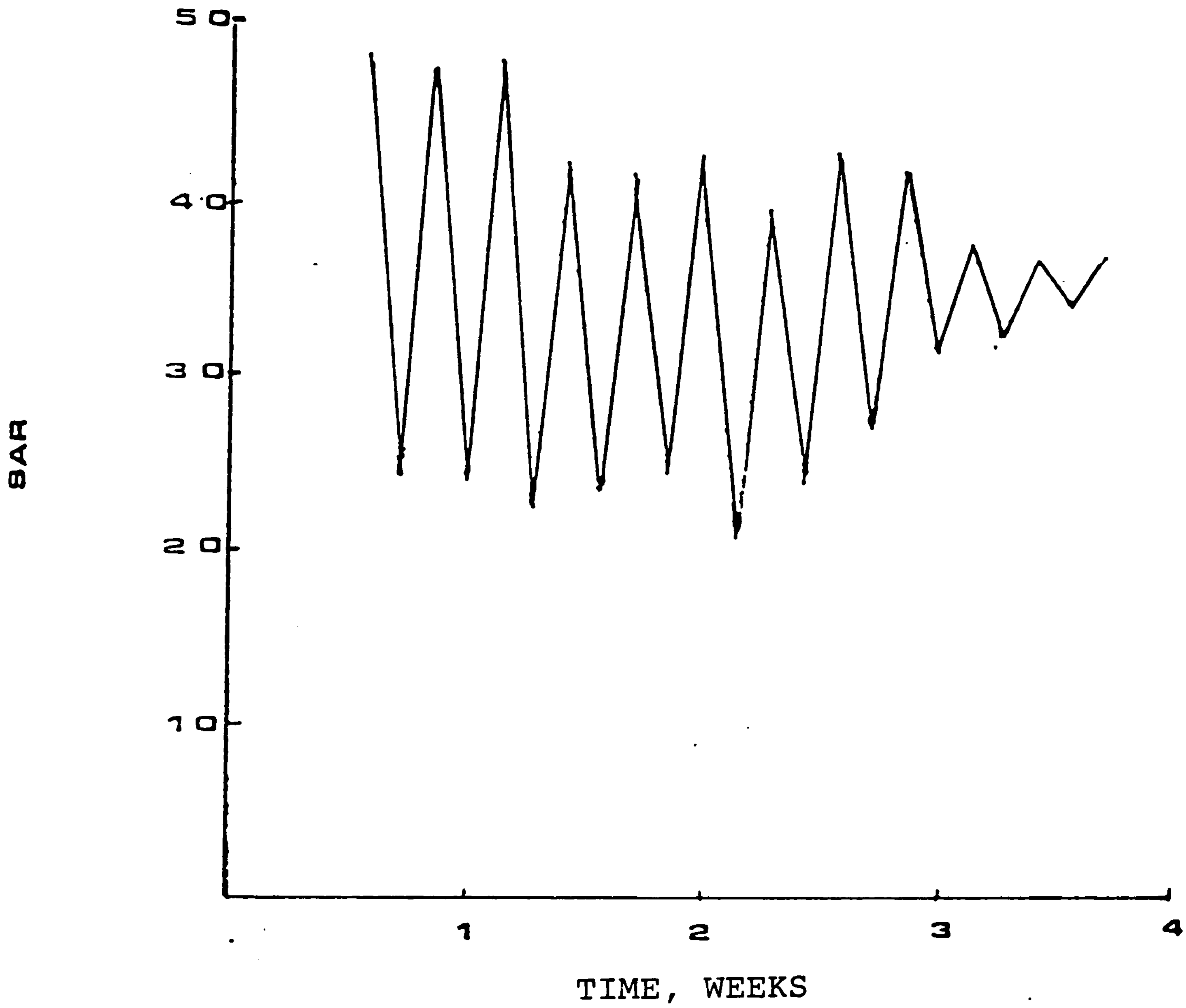


FIGURE 21 SODIUM ADSORPTION RATIOS, TANK 2

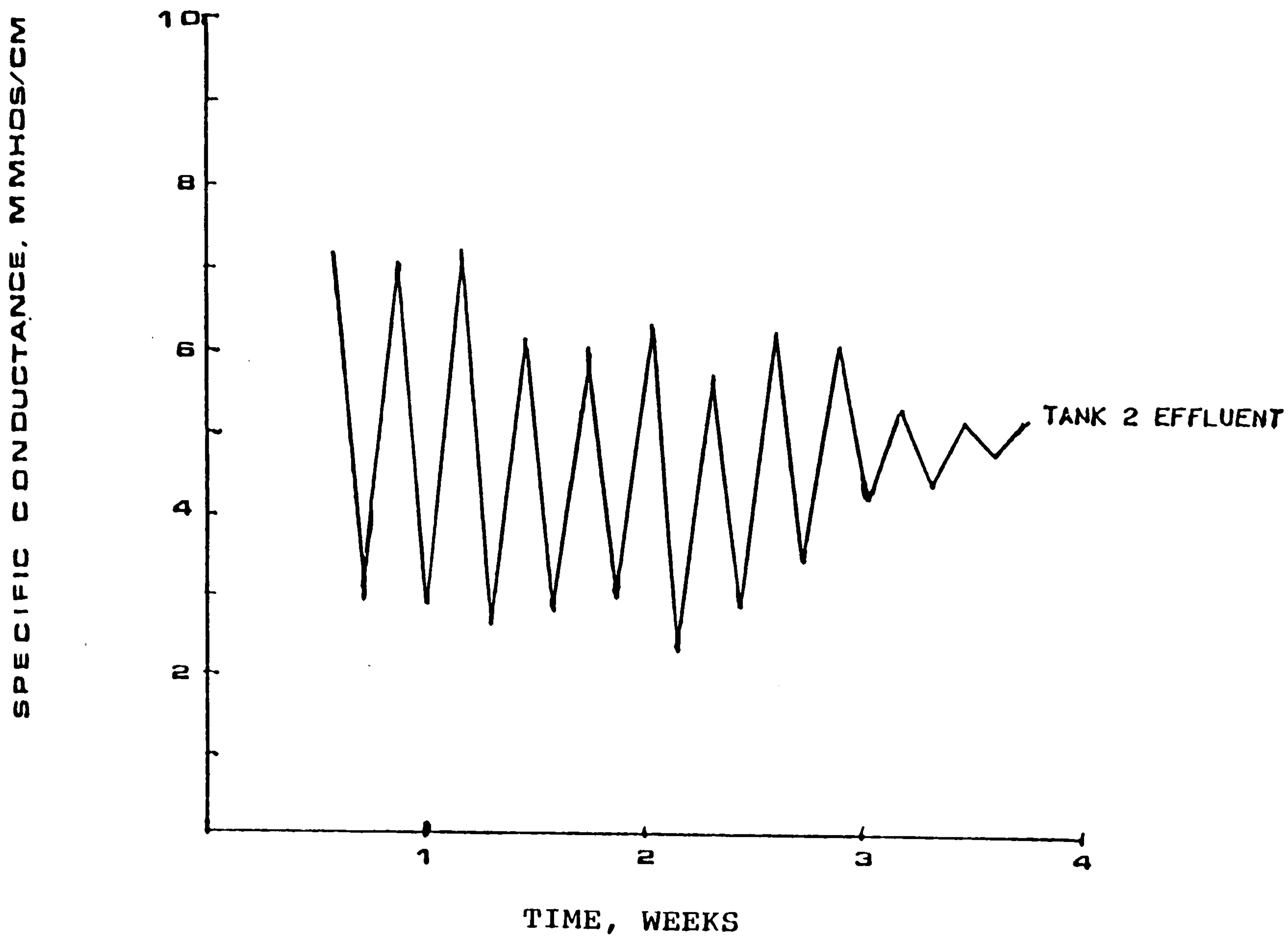


FIGURE 22 SPECIFIC CONDUCTANCE, TANK 2

hazard on the basis of classification criteria established by the United States Department of Agriculture. A water which has been classified as having a very high sodium hazard may tend to break down the aggregation of the soil grains and render the soil less permeable (34). Thus, septic tank effluent containing water softener regeneration wastes may precipitate soil absorption field failures.

Corey et. al. (15) found that hydraulic conductivity would not be lowered in a soil absorption field receiving water softener regeneration wastes, even though such wastes contribute a high SAR and specific conductance, unless water of low soluble salt concentration such as rainwater were allowed to enter the soil. The condition that rainwater not be allowed to enter the soil appears unreasonable and thus seems to invalidate the finding of the study. Furthermore, the study did not actually sample septic tank effluent, but rather sampled the contents of a septic tank immediately below the scum layer. Since density stratification of the chloride ion concentrations was found in Tank 2 of this study, soluble salt concentrations obtained at a depth immediately below the scum layer might be significantly lower than the concentrations in the actual septic tank effluent.

A second issue of concern involving specific conductance concentrations in a water is that of reduced crop yield as a function of salt tolerance. Some crops, particulary garden vegetables, show a marked crop yield reduction at specific conductances of 4.77 mmhos/cm. Thus, the area of a soil absorption field receiving water softener regeneration wastes might not be suitable for the growth of some plants.

Phase Two Test Results

The results of the second phase of experimentation where simulated water softener regeneration wastes were added to the bench-scale septic tank which had formerly operated as a control, indicated reduced performances in all areas monitored. This reduced performance can be attributed to the simulated water softener regeneration waste additions. Graphs indicating results of this phase of experimentation also indicate the results of the first phase of experimentation for comparison purposes.

Chemical Oxygen Demand

Figure 23 shows the results of the chemical oxygen demand analyses. As can be noted, after the fourth week, when the septic tank began receiving simulated water

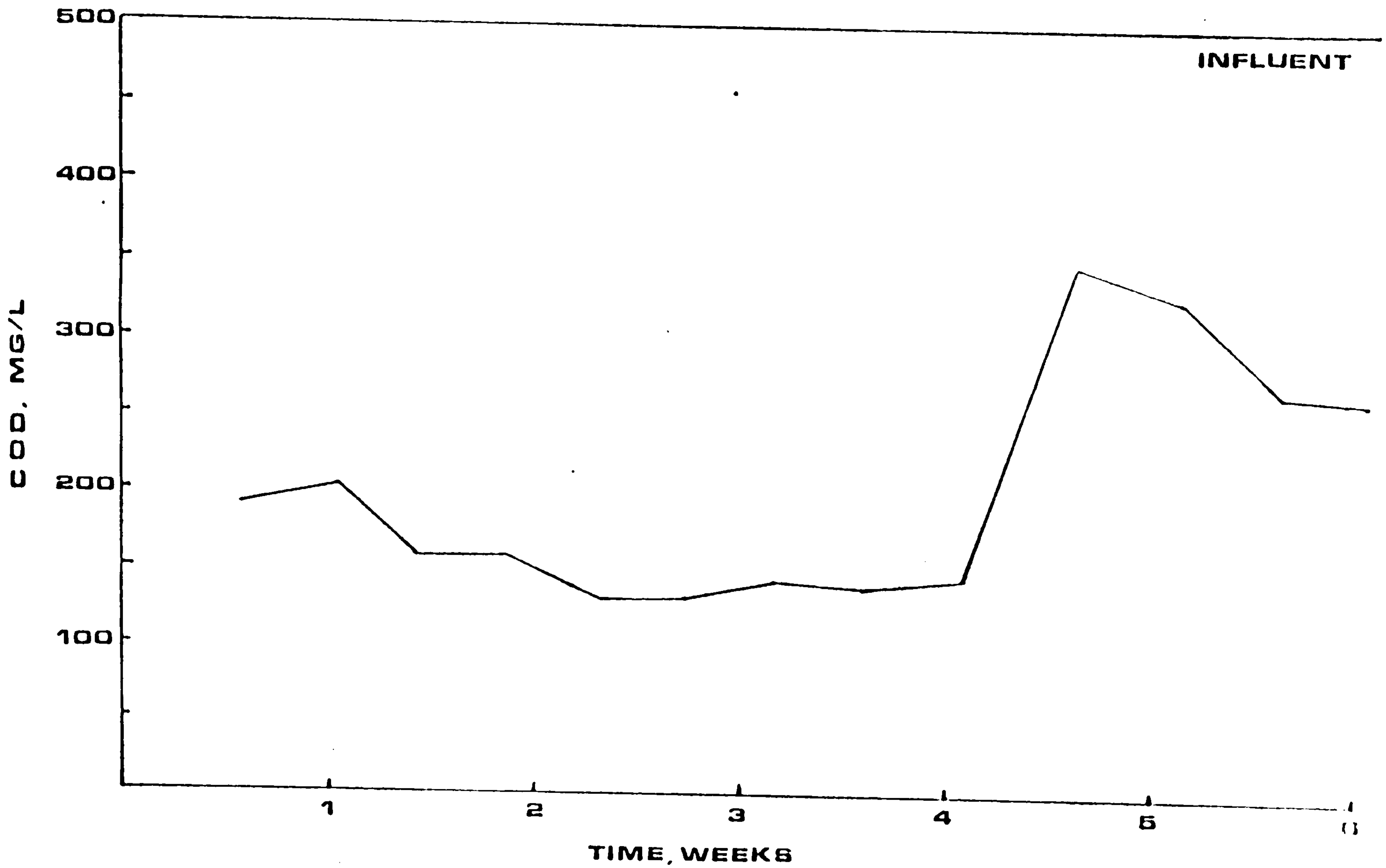


FIGURE 23 CHEMICAL OXYGEN DEMAND

softener regeneration wastes, there was a marked rise in COD concentrations in the tank's effluent. This marked rise in concentrations and ensuing trend of high concentrations indicated a reduced biological treatment by the tank. Thus, it can be assumed that a full scale operating tank would exhibit reduced biological treatment after the addition of water softener regeneration wastes.

Mixed Liquor Suspended Solids

Presented in Figure 24 are the results of the mixed liquor suspended solids analyses. The reduced concentrations in MLSS after the addition of the simulated water softener regeneration waste further substantiate the results of the chemical oxygen demand analyses. It can be postulated that not only reduced biological treatment but also an increase in sludge accumulation might occur in such a tank since fewer numbers of bacteria would be present to biodegrade solid matter entering the tank.

Chloride

The results of the analyses performed on the contents of the tank to determine chloride ion concentrations at three heights from the bottom of the tank are shown in Figure 25. It should be recalled from the

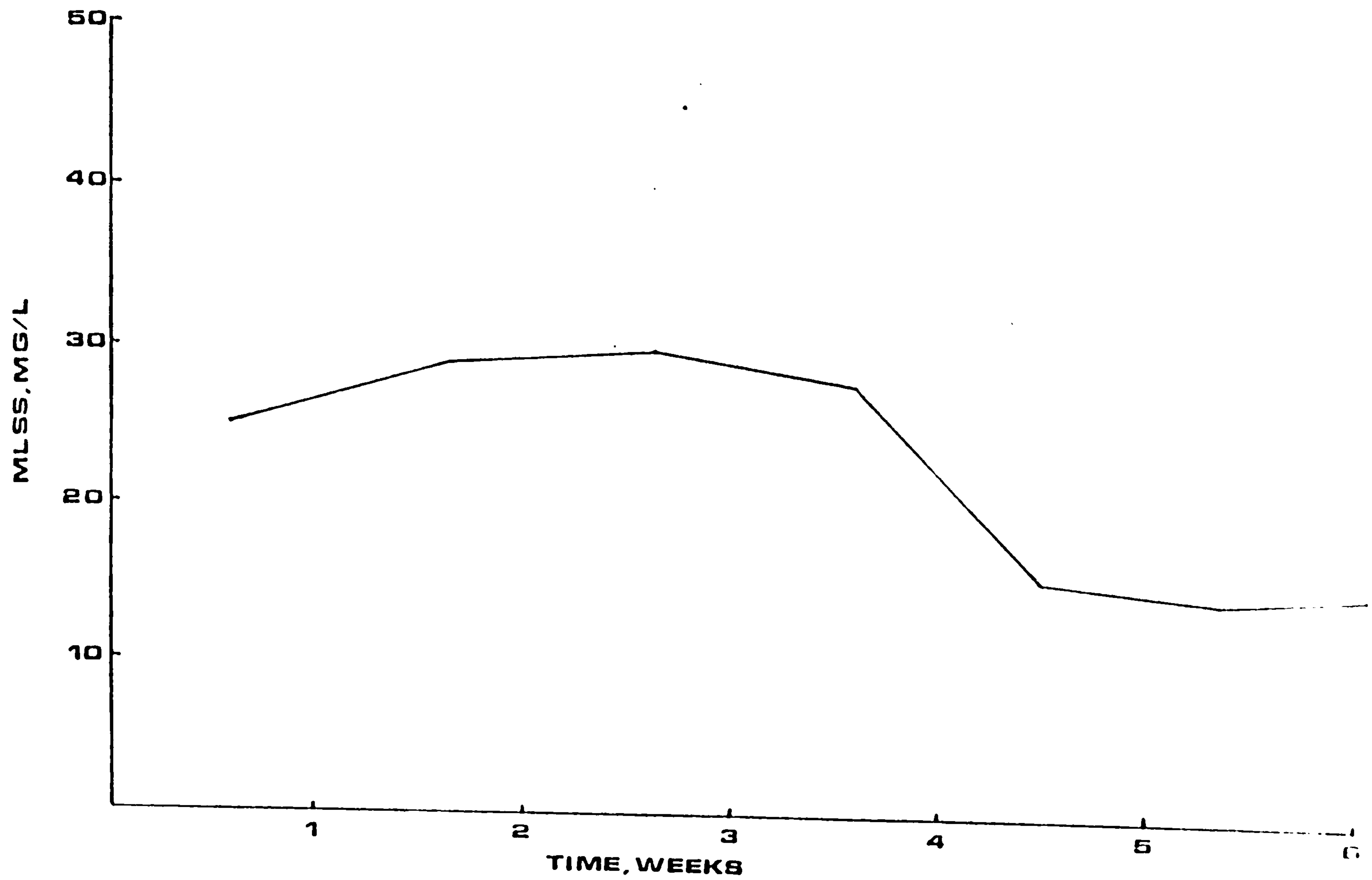


FIGURE 24 MIXED LIQUOR SUSPENDED SOLIDS

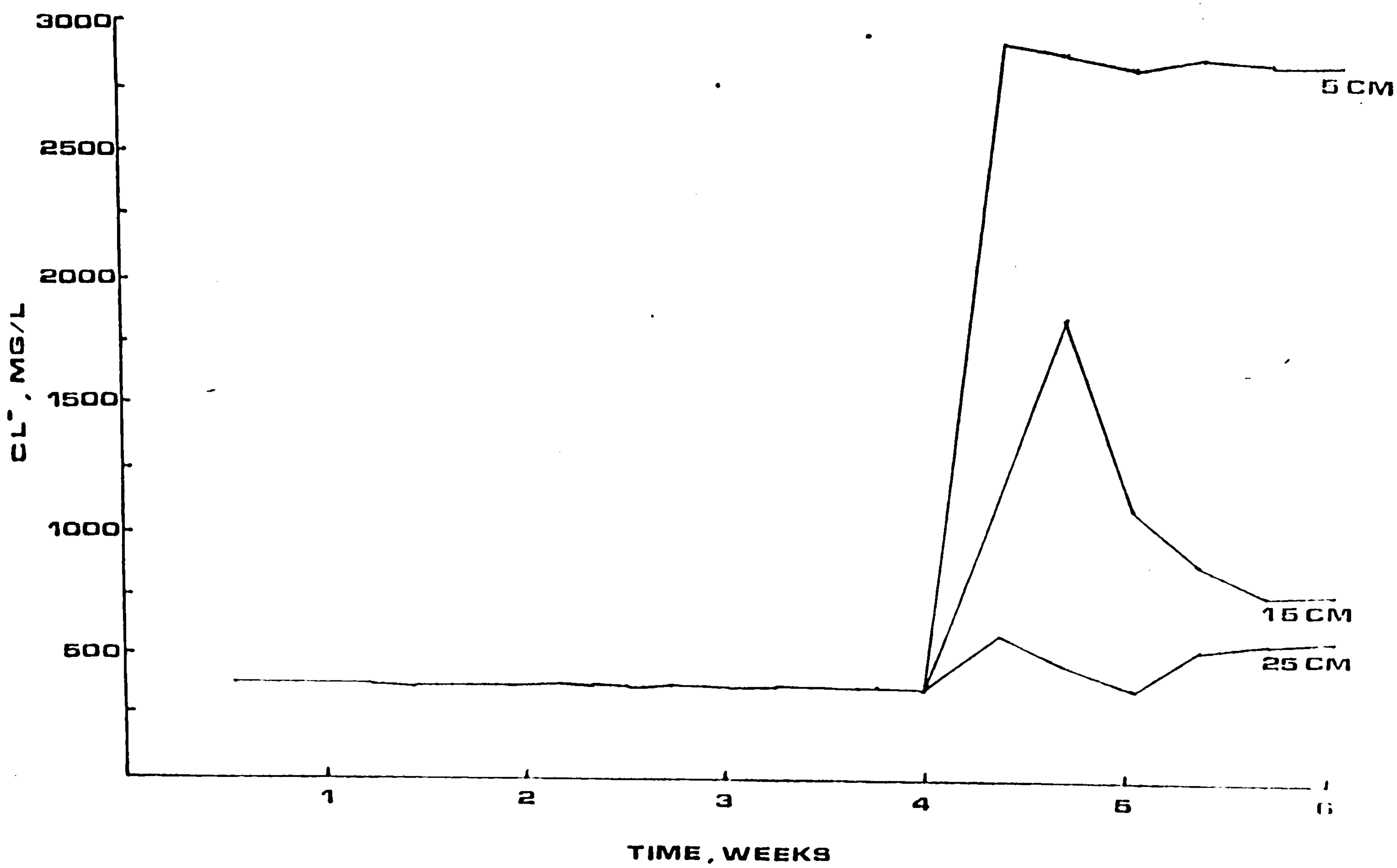


FIGURE 25 CHLORIDE ION CONCENTRATIONS

first phase of experimentation that the chloride ion concentrations remained almost constant at the three heights during that phase. However, in the second phase, the results indicated much the same pattern as was seen in the experimental tank in the first phase. It should be recognized that the concentration at the 5 cm height was slightly greater than that in the experimental tank of the first phase although the concentration of sodium chloride in the simulated water softener regeneration waste remained constant throughout both experimental phases.

A pattern of density stratification was seen in the tank which was expected on the basis of the first phase results. However, whereas in the first phase a period of stabilization occurred, density stratification was readily established in the tank in the second phase. This difference in density stratification stabilization patterns may be attributable to the fact that the tank volume and scum accumulation was already established prior to the first simulated water softener regeneration waste addition.

The results of the effluent chloride ion concentrations from the tank used in the second phase of experimentation are presented in Figure 26. The effluent chloride concentration rose rapidly after the addition of the regeneration waste.

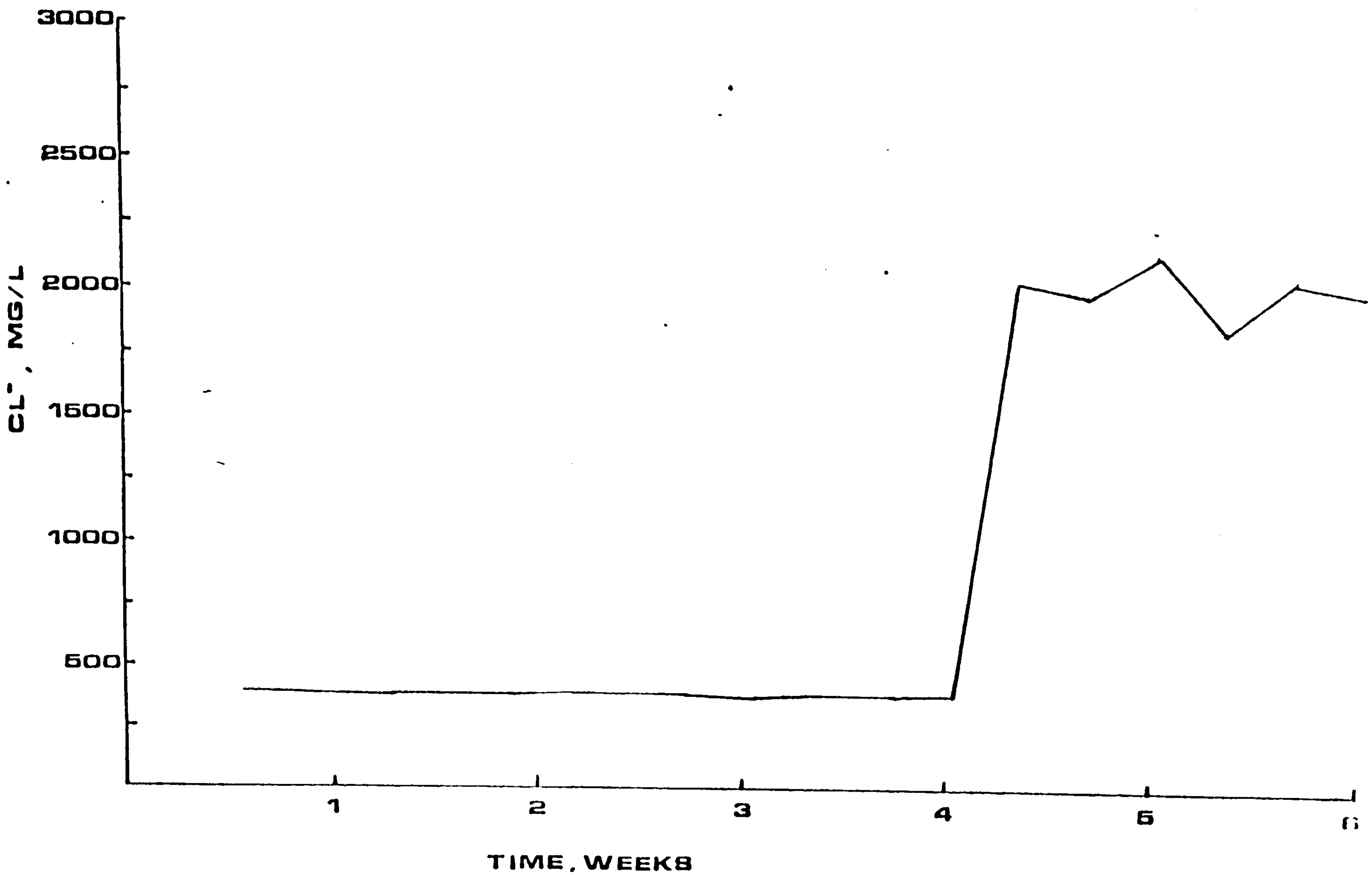


FIGURE 26 EFFLUENT CHLORIDE ION CONCENTRATIONS

Sodium

The sodium ion concentrations in the effluent were computed in the same manner for second phase as for the first. Therefore, comparing the results of the sodium analyses to those for chloride indicates a direct relationship. The increased sodium ion concentrations in the tank's effluent is indicative that possible adverse effects on soil absorption field performance might result if this effluent were so introduced. A comparison of the results of the second phase with the results from the experimental tank of the first phase yields similar results (see Figure 27). Therefore, the same conclusions concerning the high associated sodium adsorption ratios and specific conductance values may be drawn.

Calcium Ion and Total Hardness Analyses and Magnesium Ion Determination

The calcium ion and total hardness concentrations of the effluent of the tank remained constant since the addition of simulated water softener regeneration waste did not contribute any additional calcium or magnesium ions. Table 8 shows the average results of the calcium ion and total hardness analyses and the magnesium ion

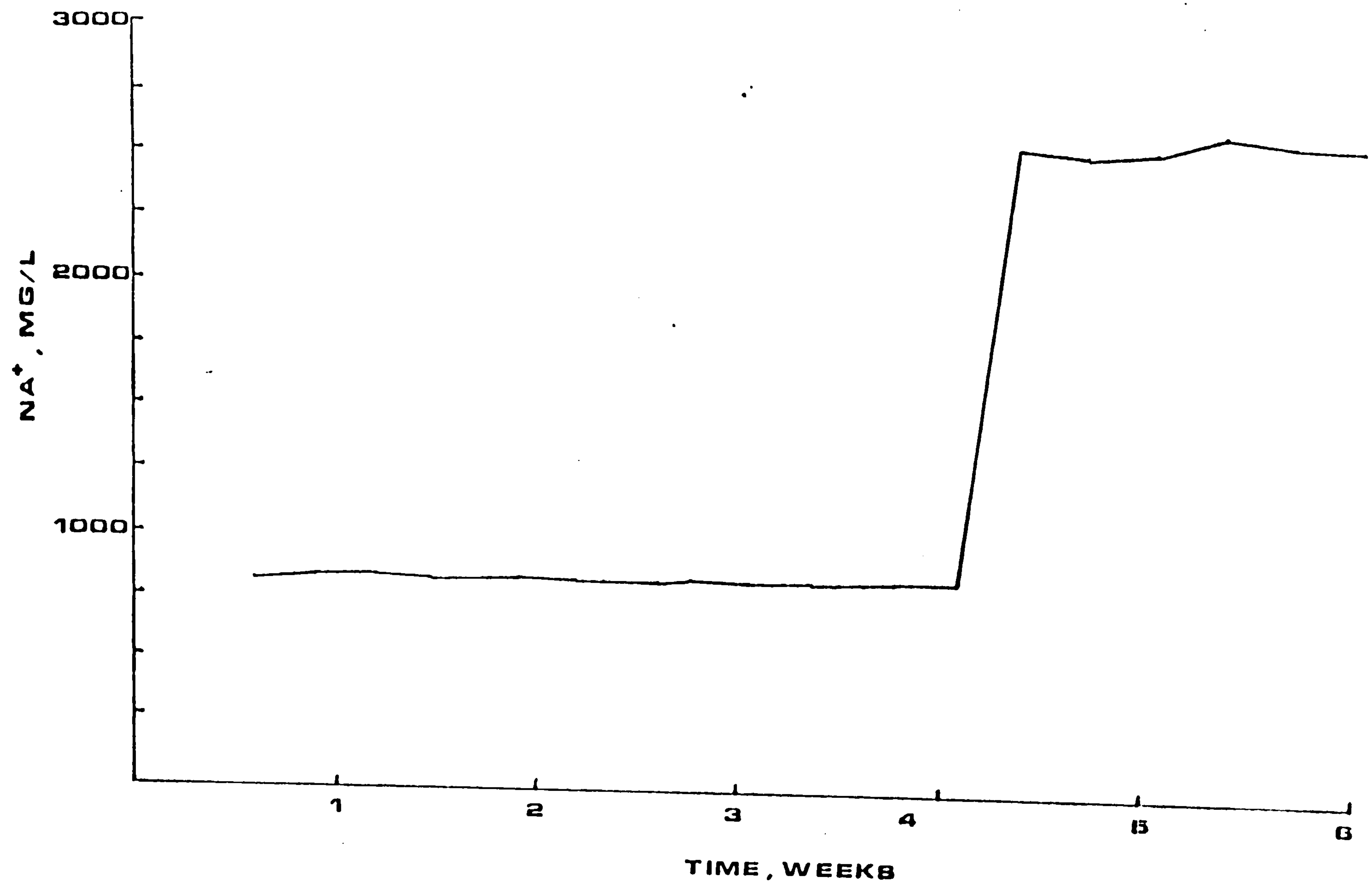


FIGURE 27 EFFLUENT SODIUM ION CONCENTRATIONS

TABLE 8

CALCIUM ION AND TOTAL HARDNESS ANALYSES AND MAGNESIUM ION DETERMINATION RESULTS

Calcium	Total Hardness	Magnesium
137 mg/l as $CaCO_3$	328 mg/l as $CaCO_3$	191 mg/l as $CaCO_3$
56 mg/l as Ca^{++}		46 mg/l as Mg^{++}

determination found by subtracting the average calcium ion concentration from the average total hardness concentration of the effluent.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Although the research conducted on the effects of home water softener regeneration wastes on septic tank system performance was confined to a bench-scale laboratory examination, the results were significant, and the following conclusions and recommendations were drawn:

Conclusions

1. The addition of simulated water softener wastes to one of the bench-scale septic tanks of this study resulted in a value for the reduction of influent COD concentration that was 24% less than the reduction obtained with the control tank. Similarly, once simulated water softener regeneration waste was added to the control tank, a corresponding increase in effluent COD concentrations was noted.

2. Bacterial populations were decreased in the tank receiving regeneration waste in the first experimental phase. Once the tank used in the second phase began receiving regeneration waste, its bacterial populations were also decreased.

3. The MLSS data suggest that the rate of sludge accumulation would increase in a tank receiving water softener regeneration wastes because the rate of anaerobic sludge stabilization in the tank would decrease. Thus, such a tank might require more frequent sludge pumpings.

4. The effluent produced by a tank receiving water softener regeneration wastes had high SAR and specific conductance values indicating that soil permeability could be decreased resulting in potential soil absorption field failures.

5. The high specific conductance values obtained also indicate that the soil absorption field area receiving such wastes might

not be suitable for certain types of plant growth, particularly garden vegetable crops.

6. Potential contamination of potable groundwater supplies might result from the high chloride ion concentrations in the effluent of a septic tank receiving water softener regeneration wastes.

Recommendations

1. Further research should be pursued on a full-scale septic tank receiving domestic sewage and actual home water softener regeneration wastes from tank start-up as well as on an established full-scale tank. The impacts of a fluctuating wastewater flow rate, the presence of solids in the wastewater, and varied organic loading of actual domestic wastewater should be addressed.

2. The effects of the introduction of actual septic tank effluent containing water softener regeneration wastes on the soil absorption field should be investigated.

3. Appropriate disposal alternatives for home water softener regeneration wastes should be investigated, such as the use of deep well injection or evaporation ponds.

4. Investigations concerning the minimum horizontal distance required for reduction of chloride ion concentrations contributed by home water softener regeneration wastes to groundwater should be made with possible revision of the minimum distance required between components of a septic tank and sources of potable water supplies.

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