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by
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Dr. Laak has written 7 monographs, 18 professional journal articles, 15 technical reports, contributed to 21 national and international conference proceedings and has lectured extensively at conferences, institutes and universities. A member of several professional societies, he has received awards from the Canada Council and the Connecticut Society of Engineers.

PREFACE

This book is about onsite, energy-efficient, low-cost wastewater disposal systems for individual homes, groups of dwellings and commercial and some industrial applications. The required engineering design steps are outlined in detail so that easy as well as difficult conditions can be accommodated. A variety of pretreatment designs, such as multicompartment gas-baffled septic tanks, extended air, lagoons, oxidation ditches, greywater, blackwater and sand filters are presented. Innovative designs, such as a passive denitrification system, high groundwater seepage fields, a methane generator design and various land disposal schemes are outlined. The book can be used for planning, design, management, repairs and alterations.

The book is primarily intended for use by professionals with backgrounds in sanitary enginering, hydraulics and soils. Although aimed at this sector, the book does not preclude its use by other disciplines. The author wishes to improve the planning, design and operation of subsurface disposal systems and to clarify the fundamental engineering principles involved.

The information and data within this book are based on actual field experience, research and literature. The author, having worked with town and state sanitary engineers, sanitarians and contractors, fully realizes the impact of the codes governing sewage disposal systems. He is also aware that approval of plans and specifications by the appropriate agency is necessary and that adherence to the codes is obligatory. This book is to provide consultants with background material that is often missing in the codes.

Professor Kent Healy and numerous graduate students contributed significantly. Mrs. Mary Eady edited and typed the final manuscript.

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CHAPTER 1

INTRODUCTION

Today in Central Europe and North America about 20-30% of the population uses individual sewage disposal systems or small treatment plants for waste disposal. In the developing countries, public sewers in cities reach 70% of the urban population, whereas in rural areas only 8% of the people have a disposal system; others have no system at all. The predictions are that the technology for small onsite wastewater treatment plants will remain a significant contributor to environmental protection as long as people prefer to live in suburban and rural settings. Any improvement in the technology is assumed to improve the quality of life. Public sewers without adequate sewage treatment remain an ecological hazard. The United States has about 22,000 public treatment plants with a design life of 20 years.

The disposal of human excrement and other wastewaters has always been of concern to man. The Greeks installed hot and cold water plumbing systems, and the Romans reused public bathing water to flush public toilets; however, wastewater was never "artificially" treated, but was discharged out of the cities by means of ditches. The Greeks and Romans knew that drinking water and wastewater must be kept separated. Cesspools and pit privies had been used for thousands of years for individual systems. It is claimed that after the fall of the Roman Empire, about 476 A.D., public health technology was lost. The concept and practice of keeping sewage and public drinking water separated was discarded. During the Dark Ages, cities remained small (less than 100,000 people), with wells and cesspools dug next to each other. The Roman water supply aqueducts were closed. The city management lacked the technology for the prevention of epidemics.

Along with the technical revolution came an influx of people into the unprepared cities. With the development of industry came the first marketable flush toilet (1810); and with the population growth, city planning and public works had to be reorganized. The first carefully engineered sewer was built in Hamburg, Germany in 1848; open as well as closed sewers had been built before this date, but without the use of engineering principles. The several Royal Commissions appointed to study and report on the wastewater problems in England between 1850 and 1900 all concluded that the best method of sewage disposal was on land. By 1876, a total of 64 cities in England were spreading their sewage on land without prior soil surveys. The problem of water or river pollution was especially acute in England because river flows were relatively small compared to the volume of sewage discharged. Various land disposal schemes were developed for the cities in Europe as well as in America, including curtain drains, crop and hay farming, and polishing fish ponds. Laws were passed regarding land acquisition rights, and several cities practiced and researched the use of wastewater nutrients for crops.

It was soon discovered that if sewage was pretreated (settled, etc.), the effluent seeped into the sewage land areas much faster. Frankland, who developed the intermittent sand filter to reduce the land area required, also noticed that pretreatment and proper loading rates were essential. All overloaded land areas, filters, etc. became clogged. Raking or rototilling the soil or sand surface disturbed the clogging layer on the soil surface, and the overload of sewage could again be applied for a period. Cities grew at a rapid rate during the industrial growth era, but land disposal areas were not increased proportionately. For example, Leeds, England, expanded so rapidly in one period that each week 1 ac (0.4 ha) of additional land area was required.

It is said that Frankland's filter fostered the development of the trickling filter; hence some large cities converted to biological treatment. About half of the large cities in 1923 presettled their sewage before discharge, and many cities today still continue to discharge raw sewage into water bodies. Land disposal on a large scale became less fashionable as well as less economical by 1900, because cities needed the adjacent lands, and too many land systems had become overloaded, neglected and odorous. The Royal Commission of 1898 required a qualified caretaker for land disposal areas. Small subsurface infiltration trench systems were used for raw sewage early in the nineteenth century. At that time it was believed that the distribution pipes would become plugged, and Frankland himself warned against these systems. Later it was, of course, discovered that a presettling tank or septic tank would reduce or eliminate this problem. Despite skepticism, Olcott reportedly had installed 70 such systems that were operating successfully. Dunbar reported that many land disposal systems operated for over 20 years without losing their infiltration capacity to accept a proper load.

During this period of land disposal for large cities (1800–1910), many of the same failure problems occurred as are reported today: (1) insufficient pretreatment; (2) overloading from increased water use; (3) improper curtain drains; (4) "soil clogging" and flooding of the system; and (5) raising the groundwater table at or near the site, causing flooding, bad odor and a public health hazard.

This book presents the design procedure for subsurface domestic wastewater systems, including the field investigations required to avoid failures caused by lack of proper information and design considerations. The author believes, as was stated by Dunbar in 1907, that land disposal of wastewater requires the same amount of careful engineering as do other methods of sewage disposal and treatment. The onsite system technology is now better developed, and it has become feasible to plan for the future using sewerless land-use concepts. Sewerless housing needs qualified managers and service personnel capable of maintaining sewerage systems and treatment plants.

LARGE VS SMALL TREATMENT PLANTS

Increased production and consumption is believed to lead to a better life, and is accompanied by an increase in the volume of wastes to be treated and recycled, or in the amount of residue that must eventually be disposed of. The concept of small treatment plants would appear to conflict with growth, i.e., it limits the amount of wastewater that can be generated in a small area. Through the use of larger rivers and lakes to receive liquid effluent from distant areas, wastewater growth is not as limited, according to conventional thinking. The modern notion developed around the principle that a few large treatment plants are desirable, because control over wastewater can be achieved with the least cost, and manpower and additional treatment can be readily added later when ecological effects show the need.

It is believed that sewering and regionally controlled sewage treatment plants appeal to regulatory agencies because this scheme appears to offer a more comprehensive solution: far fewer small plants to inspect, less personnel to train, and greater economy in purchasing chemicals, tools and other materials. However, the problem is not one-sided, nor is it that simple. Cost-effective studies and environmental impact statements, which are recent requirements, show that some areas should be planned using small treatment plants or onsite disposal systems.

Many believe that waste should be eliminated or treated at or near the source, and that this will encourage individuals to economize or produce less waste. Ecologists and conservationists do not believe that a large collection and concentration of wastes in one spot is a sound principle (although it is justifiable on economic grounds for cities).

Recent field surveys have shown that large and small treatment plants perform equally well, i.e., plant efficiency depends upon the degree of service/ maintenance and not on size. The larger the treatment plant or factory, the more complex the administration and control.

Advantages and Disadvantages of Central Wastewater Treatment with Effluent Discharge to Receiving Bodies of Water

Advantages

Çentral pollution-control plants that use comparatively little space to treat the liquid portion of sewage by physicochemical or biological methods are accepted as suitable for urban areas where the population density is high. Such works permit high production of wastewater in a small area, and the homeowner has relatively little bother with the system. In addition, the costs for maintenance, alterations, control, sewer pipe and treatment are met through taxation. The construction costs are subsidized by state and federal governments, which receive their revenue from a broad population base.

Disadvantages

The major disadvantage is that when sewage is transported to a central point where partial treatment is provided, the residue or economically untreatable materials are released into the environment at one central point, causing potentially greater environmental degradation and hazards more difficult to control. Today the trace materials that are not removed by accepted treatment methods (secondary treatment) cast doubt on the wisdom and economy of sewering and sewage treatment with effluent discharge.

Another disadvantage has been the problem of sludge disposal. Usually the treatment plants located in the cities offer no economical sludge disposal method. City sewage generally contains industrial wastes with toxic components, which recently have disqualified sludge as a "good" soil conditioner. Some farmers will no longer accept sludge for fear of heavy metals. The burning of sludge has been found by many to be expensive because auxiliary fuel is needed. The use of waste ashes is also limited by the presence of heavy metals.

With the growing awareness of energy limits, the energy requirement for a treatment plant will become a significant added consideration. The margin of error has increased in sizing sewers, estimating growth for the entire area and predicting the future quality of raw sewage. The result can be over- or underdesign. All in all, the cost benefit analysis has such a great chance of error that any advantages are outweighed.

Advantages and Disadvantages of Onsite Wastewater Disposal

Advantages

The economic advantage is the low cost to governments because the cost is borne by the user. A single-system failure constitutes a low hazard to the environment and, as will be shown, the system fails gradually, thus providing advance warning. The low hazard level stems from the fact that family sewage never contains pathogenic organisms unless one or more of the family or their guests excrete pathogens.

City sewage usually contains pathogens because of the probability that out of about 100,000 people, one person may be ill. Properly functioning onsite disposal systems do not discharge an effluent to surface waters, and few treatment plant operators are required because of limited accompanying sampling and chemical laboratory analysis, laboratory equipment and toxic chemicals for analytical work. Onsite systems have lower energy consumption and water use, and produce less sludge. This sludge is also more suitable for soil conditioning.

Disadvantages

The greatest disadvantage has been the land area required to dispose of the wastewater generated. How much land area is really required and what soil conditions are suitable has been studied for over 100 years. The approximate land area required is shown in Table 1-1.

The second disadvantage is that the homeowner does not always look after the system. Problems may arise if repairs are not carried out economically and promptly. In some cases groundwater has been polluted by improper location and installation of onsite systems.

The onsite system suffers more from technological development than large sewage treatment plants. The improvements developed by researchers and industry are difficult to implement because onsite systems need local approval. Onsite systems are controlled like plumbing and electrical installations, i.e., regulations are written in such detail that few innovative ideas or designs can readily be accepted. The incentive to improve is minimal because no cost advantages are allowed through smaller land area requirements and better designs. The local codes are the design and are widely accepted as the best available or workable technology.

Table 1-1 Approximate Number of People That Can Be Accommodated per Acre of Soil Disposal System with Pressure Water System Using Conventional Plumbing Fixtures

Pretreatment Works	
Septic Tank	1 ac/30,000 people–minimum 50 ft^2 (5 m^2)
Packing Plant	1 ac/30,000 people–minimum 900 ft^2 (80 m^2)
Aerated Lagoon	1 ac/3,000 people
Lagoon	1 ac/100–1,000 people
Underdrain Filter Bed	1 ac/500 people
Soil Disposal Areas	
NODAK System	1 ac/500 people
Min. Leaching Field or Pits	1 ac/300 people
Max. Leaching Field or Pits	1 ac/100 people
Irrigation 1 in./wk (2.5 cm/wk) for 6 months/yr	1 ac/1,000 people

EXAMPLE: HOW TO CALCULATE LOT SIZE

Assuming 25-ft (7.5-m) setback requirements for a 1100-ft^2 (100-m^2) house and 10-ft (3-m) clearnace from property lines, the minimum effective lot with communal water is about 0.25 ac (0.1 ha) and without communal water (i.e., individual wells) about 0.5 ac (0.2 ha). Some reserve area should be added for the soil system, as well as areas that cannot effectively be used, such as slopes exceeding 15%, areas without soil cover and soils with a permeability of less than 10^{-4} ft/min (5 x 10^{-3} cm/sec).

GENERAL TYPES OF LAND TREATMENT SYSTEMS

SI - Surface irrigation for crop production (Figure 1-1)
OR - Overland runoff in poor subsoils on slopes for hay production (Figure 1-2)
RI - Rapid infiltration in permeable soils for groundwater recharge (Figure 1-3).
SS - Figure 1-4 is a definition sketch of an individual subsurface system with a well
SS - Subsurface soil systems for recharge and disposal–current design method (Figure 1-5)
SS - Subsurface soil system for recharge and disposal–new design method (Figure 1-6)
ET - Evapotranspiration system (not presented here)

Figure 1-1 Surface irrigation. Load is sprayed in 4–8 hr (2 in./week at Pennsylvania State Project; 4 in./week at Muskegon Project).

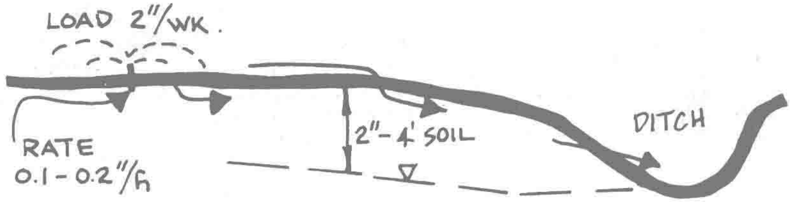


Figure 1-2 Overland runoff. Slope = 2–6%, approx. 300-ft travel to drainage ditch.

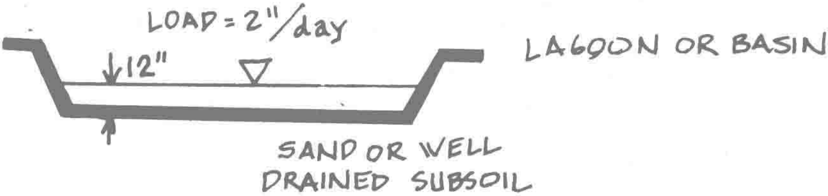
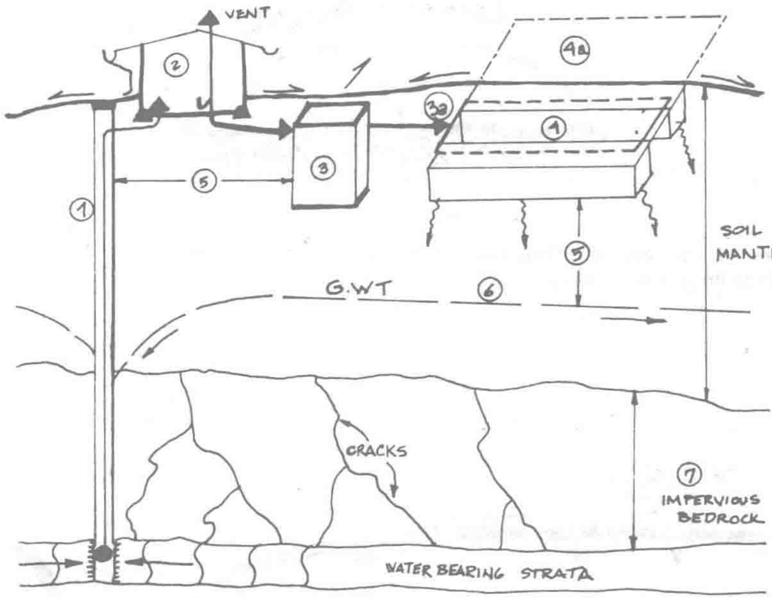


Figure 1-3 Rapid infiltration (load 14 days, rest 14 days).



(1) Drilled Well
(2) Use of Water = Wastewater Flow
(3) Pretreatment Unit (Septic tank, extended aeration plant, lagoon, oxidation ditch)
(3a) Distribution System
(4) Soil Seepage System
(4a) Research Area = Safety Factor
(5) Soil Percolation and Treatment
(6) Ground-Water Table
(7) Bed Rock (relatively impervious)

Note (5) = Protective Distances (Vertical and Horizontal)

Figure 1-4 Definition sketch: individual subsurface disposal system with a well.

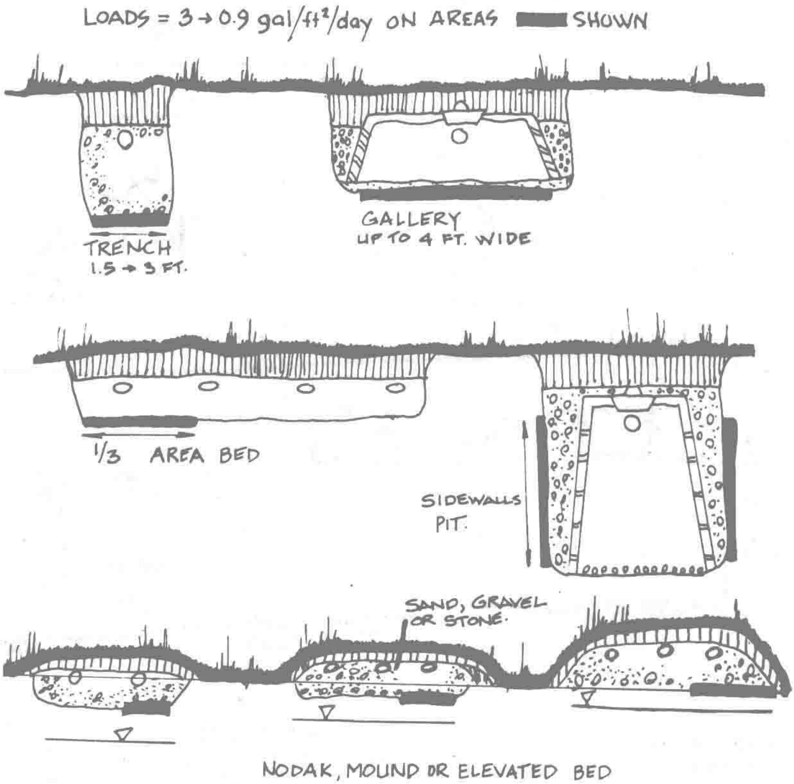


Figure 1-5 Subsurface systems–current design method.