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MICROBIAL-PLANT FILTERS (ARTIFICIAL MARSHES) FOR TREATING DOMESTIC SEWAGE AND INDUSTRIAL WASTEWATER

BY

B. C. WOLVERTON, Ph.D.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATIONAL SPACE TECHNOLOGY LABORATORIES
NSTL, MS

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INTRODUCTION

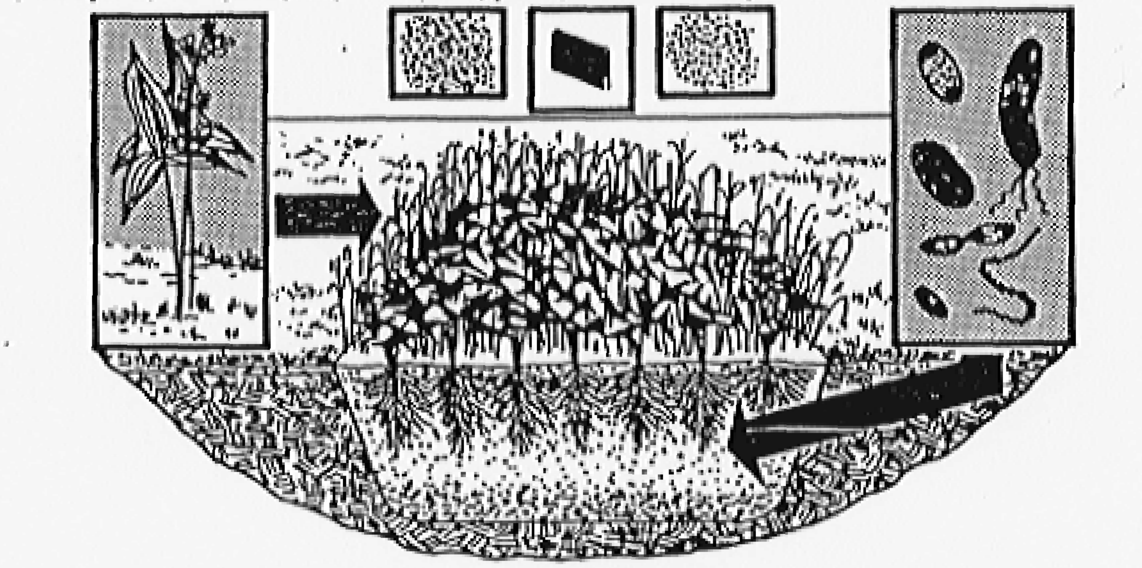
The treatment of domestic sewage and removal of hazardous chemicals from contaminated water is a problem confronting communities and cities throughout the United States and other countries. Wastewater treatment is an integral part of the water crisis that is emerging throughout the world. Even areas of the U.S. and other parts of the world with a plentiful supply of water are facing problems because the water is becoming contaminated with sewage and/or hazardous chemicals. Therefore, one of the most urgent environmental needs in the world today is a simple, low cost means of wastewater treatment and water reuse (1). A promising means of such wastewater treatment has been developed by NASA at the National Space Technology Laboratories (NSTL) in south Mississippi. During the past 14 years, scientists at NSTL have been attempting to manipulate and optimize the natural biological processes involving the symbiotic relationship between certain plants and microorganisms for space applications. A great deal of success has been achieved in developing a bio-regenerating life support system that has demonstrated potential for future space stations.

This bio-technology has immediate use on earth in wastewater treatment and other applications, Figure 1.

FIGURE 1

BIO-TECHNOLOGY

A TECHNOLOGY OF THE FUTURE



SOME PROMISING APPLICATIONS OF BIO-TECHNOLOGY:

- CLOSED LIFE-SUPPORT SYSTEMS FOR FUTURE SPACE STATIONS
- TREATING DOMESTIC SEWAGE FROM SINGLE HOMES TO LARGE CITIES
- REMOVING INDOOR AIR POLLUTANTS FROM ENERGY-EFFICIENT HOMES, BUILDINGS, SUBMARINES, ETC.
- REMOVING HAZARDOUS CHEMICALS FROM DRINKING WATER, GROUND WATER, AND RIVER WATER
- RECYCLING DOMESTIC SEWAGE INTO POTABLE WATER AND OTHER USES
- REMOVING TOXIC CHEMICALS FROM INDUSTRIAL WASTEWATERS
- REMOVING RADIOACTIVE WASTE AND OTHER HAZARDOUS CHEMICALS FROM CONTAMINATED SOIL AND WATER
- CONVERTING SEAFOOD WASTE INTO USABLE PRODUCTS AND CLEAN WATER
- WATER RECYCLING AND PURIFYING IN INTENSIVE AQUACULTURAL OPERATIONS (FISH, SHRIMP, CRAWFISH, ETC.)
- FUTURE SOURCES OF FOOD, ENERGY, MEDICINE, AND INDUSTRIAL RAW MATERIALS.

DOMESTIC SEWAGE TREATMENT

The first phase of this bio-technology was begun at NSTL in 1971 and involved the use of water hyacinth (*Eichhornia crassipes*), a floating tropical aquatic plant (2-19). This plant was used to upgrade all sewage lagoons at NSTL in 1975. By using water hyacinths in lieu of conventional activated sludge processes, NASA has realized cost savings at NSTL of several million dollars during the past eleven years of operation.

Although the water hyacinth has been effective for treating wastewater at NSTL during the past eleven years and recycling domestic sewage into potable water at San Diego, CA, it has several limitations. One disadvantage of the water hyacinth is that it is a tropical plant and can only survive in warm climates unless protected by greenhouses. High concentrations of chemical waste and brackish or salt water can also be detrimental to this plant.

In an effort to overcome some of the limitations of a water hyacinth wastewater treatment system, an advanced hybrid system was developed at NSTL which combined cold-tolerant and salt-tolerant plants with microbial filter technology. The first hybrid system consisted of an anaerobic sludge collecting and digesting chamber followed by an up-flow rock filter in which reed (*Phragmites communis*) or rush (*Juncus effusus*) were grown (20-21), Table 1, Figure 2.

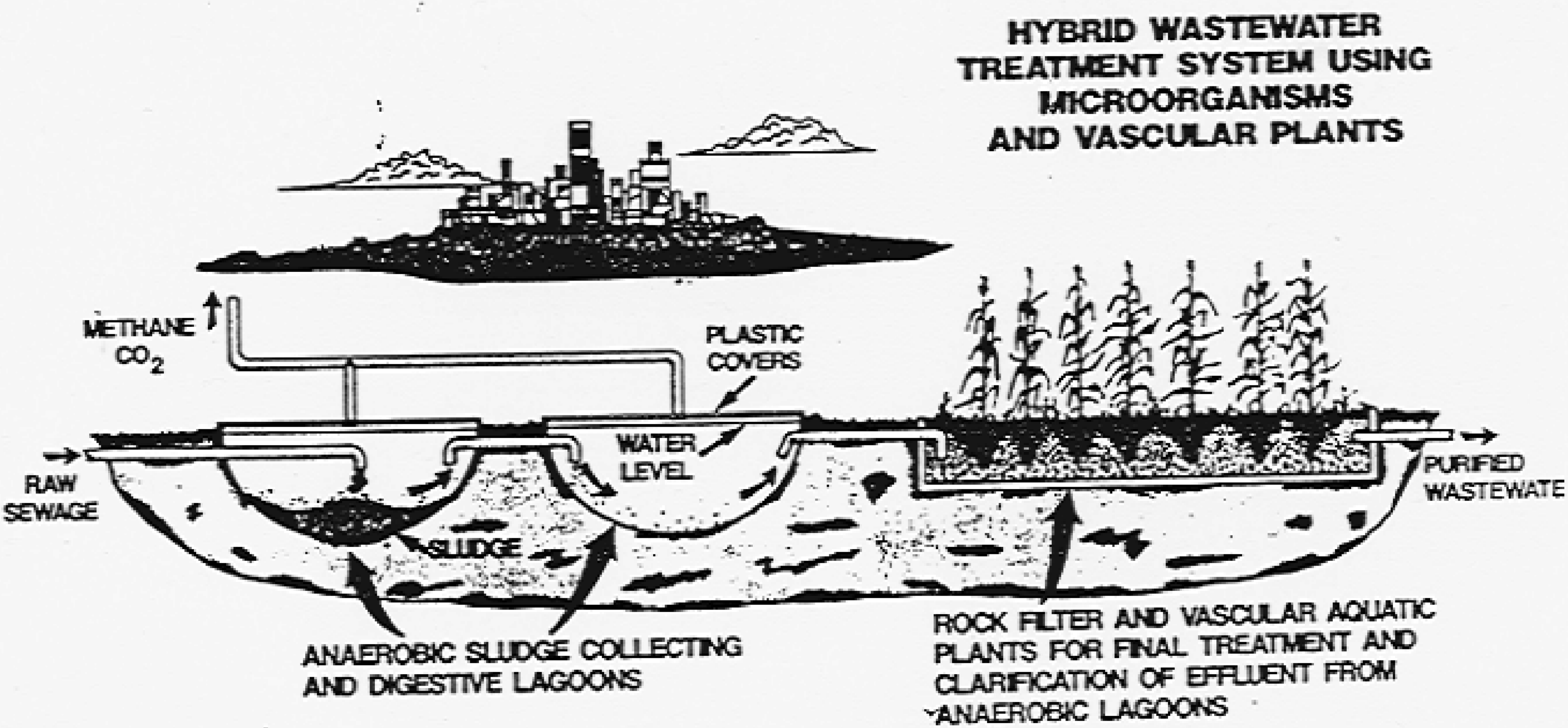
The hybrid system has undergone change during the past several years by adding aerobic and facultative lagoons to collect and digest sludge. The filter has also been changed from the up-flow process which required

TABLE 1. HYBRID ROCK-REED AND ROCK FILTERS FOR TREATING DISCHARGED WASTEWATER FROM SEPTIC TANKS AND/OR SEWAGE LAGOONS.

Filters	BOD_5, mg/ℓ^		TSS, mg/ℓ		Retention Time Hrs	Temp Avg °F
	Initial	Final	Initial	Final		
Rock	81	14	27	15	24	80
Rock-Reed	72	3	36	6	24	80

*From Reference 20.

FIGURE 2


HYBRID WASTEWATER TREATMENT SYSTEM USING MICROORGANISMS AND VASCULAR PLANTS
METHANE
CO_2
PLASTIC COVERS
WATER LEVEL
RAW SEWAGE
SLUDGE
PURIFIED WASTEWATE
ANAEROBIC SLUDGE COLLECTING AND DIGESTIVE LAGOONS
ROCK FILTER AND VASCULAR AQUATIC PLANTS FOR FINAL TREATMENT AND CLARIFICATION OF EFFLUENT FROM ANAEROBIC LAGOONS

large quantities of perforated PVC pipe to a simple channel flow with only a perforated header pipe and effluent pipe. The reeds and rushes have also been replaced in most cases by more aesthetically desirable plants such as the canna lily, arrowhead, arrow-arum, elephant ears and water iris. The canna lily, arrowhead and water iris also produce beautiful yellow, red, orange, white and blue flowers, Figures 3 and 4, Table 2.

Although microbial rock filters have been used to treat sewage for over 90 years and the ability of aquatic plants to enhance sewage treatment in natural marshes has been recognized for many years, only recently have the two processes been combined. The combination and optimization of microbial filters and higher plants into an artificial marsh has produced one of the most promising wastewater treatment technologies since development of the trickling filter process in 1893.

Although this technology is relatively simple, it is very important that sound engineering practices be used in the design of these filters. It is also important that filter depth be considered especially in the last section of the filter to assure aerobic conditions are achieved before discharge. A dissolved oxygen level of 2.0 mg/ℓ or more is desirable to achieve low BOD_5 levels (10-5 mg/ℓ).

Since the application of the microbial-plant filter is new and only a limited number of small systems have been in operation during the past several years, engineering design data is still being generated. Several small systems, 200-1,000 gal/day, have been in operation in Mississippi for several years (22). There have been one 2,000 gal/day, one 6,000 gal/day, one 10,000 gal/day and three 350,000 gal/day microbial-plant filters designed for use in Louisiana during the past year. Several of these systems are

FIGURE 3

ARTIFICIAL MARSH FILTER FOR TREATING 2000 GALLONS OR LESS OF WASTEWATER PER DAY

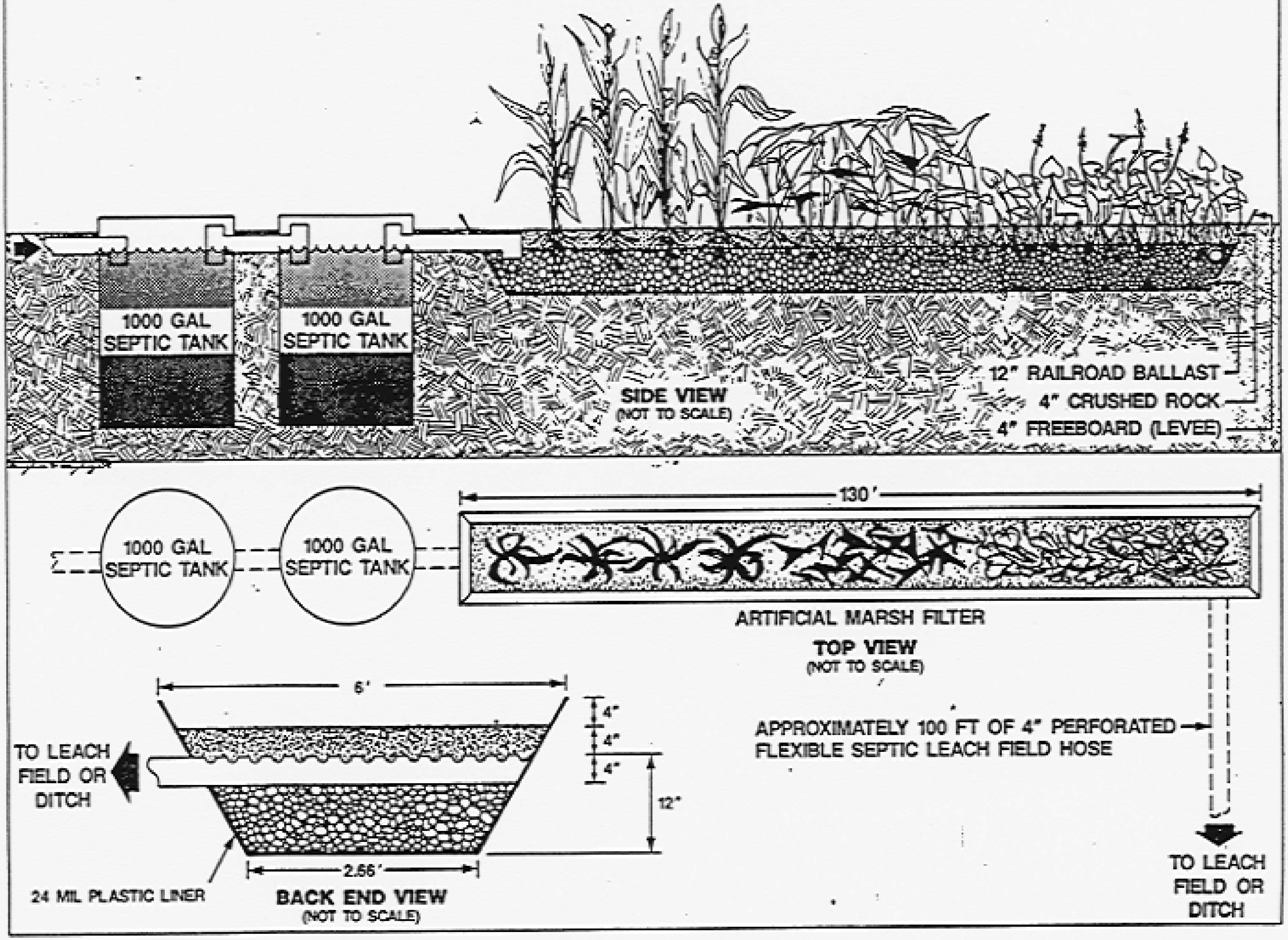


FIGURE 4

SINGLE HOME WASTEWATER TREATMENT SYSTEM USING PLANTS

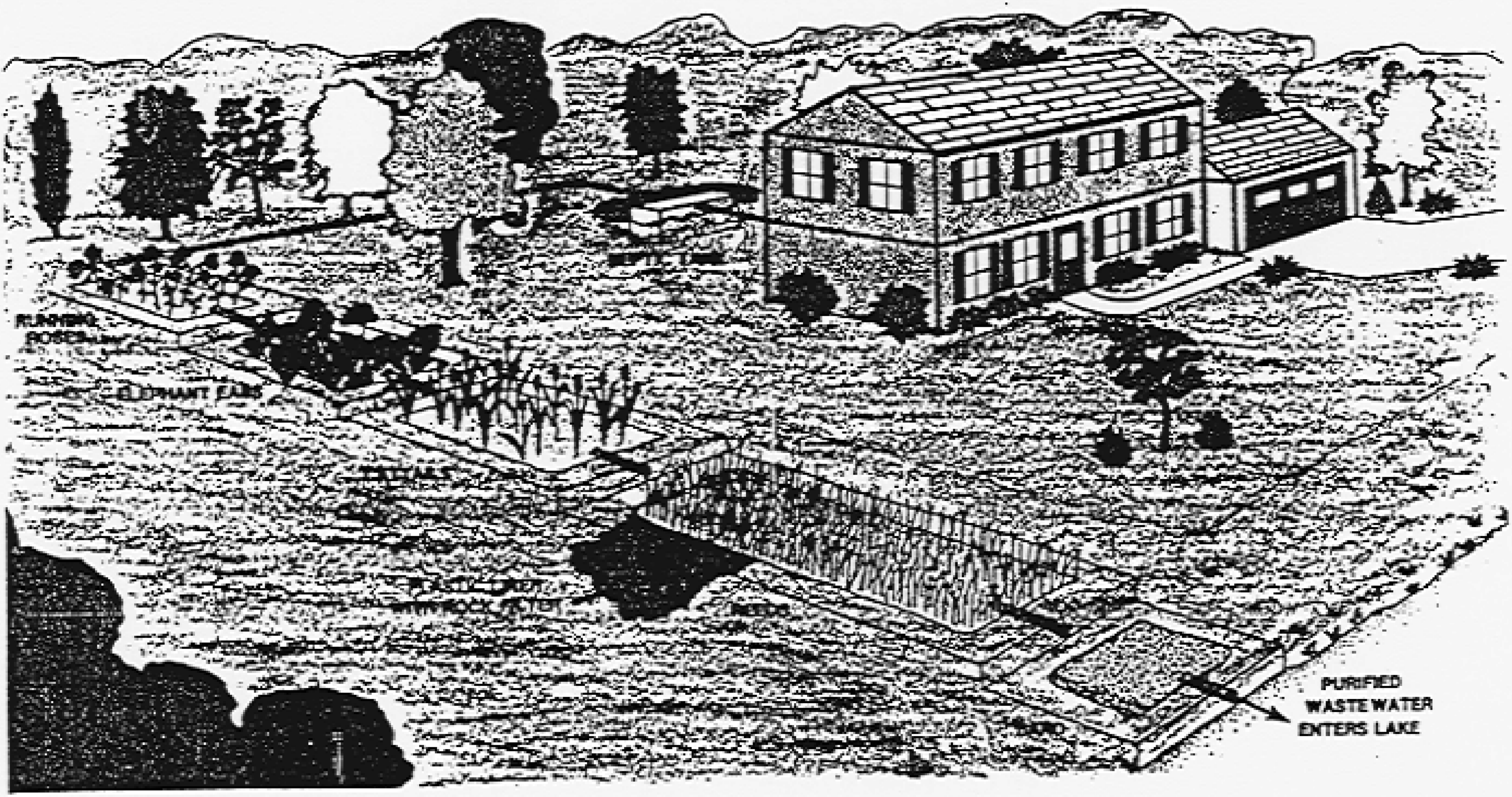


TABLE 2. ARTIFICIAL MARSHES FOR TREATING DISCHARGED WASTEWATER FROM SEPTIC TANKS AND/OR SEWAGE LAGOONS.

Marsh Plants	Retention Time Hrs	Temperature °F	BOD_5, mg/ℓ* Influent	BOD_5, mg/ℓ* Effluent
Arrowhead and Arrow Arum	24	68	75	5
		68	53	2
Canna Lily	24	68	116	12
		68	64	3

*Averages from three or more experiments under construction and hopefully will go into operation during 1986.

These filters have been designed to treat wastewater discharged from septic tanks, Figures 3 and 4, and sewage lagoons, Figure 5. These filters are also capable of treating wastewater discharged from any system provided sludge is removed to prevent filter clogging.

These filters can be designed to achieve various levels of BOD_5 and TSS removal, ranging from secondary levels of 30 mg/ℓ to tertiary levels of 5 mg/ℓ or less. They have advantages over mechanical systems in that to achieve the same level of treatment they are generally much less expensive to install and in most cases can be designed to operate by gravity flow which reduces operational and maintenance cost to only a fraction of the cost of mechanical systems.

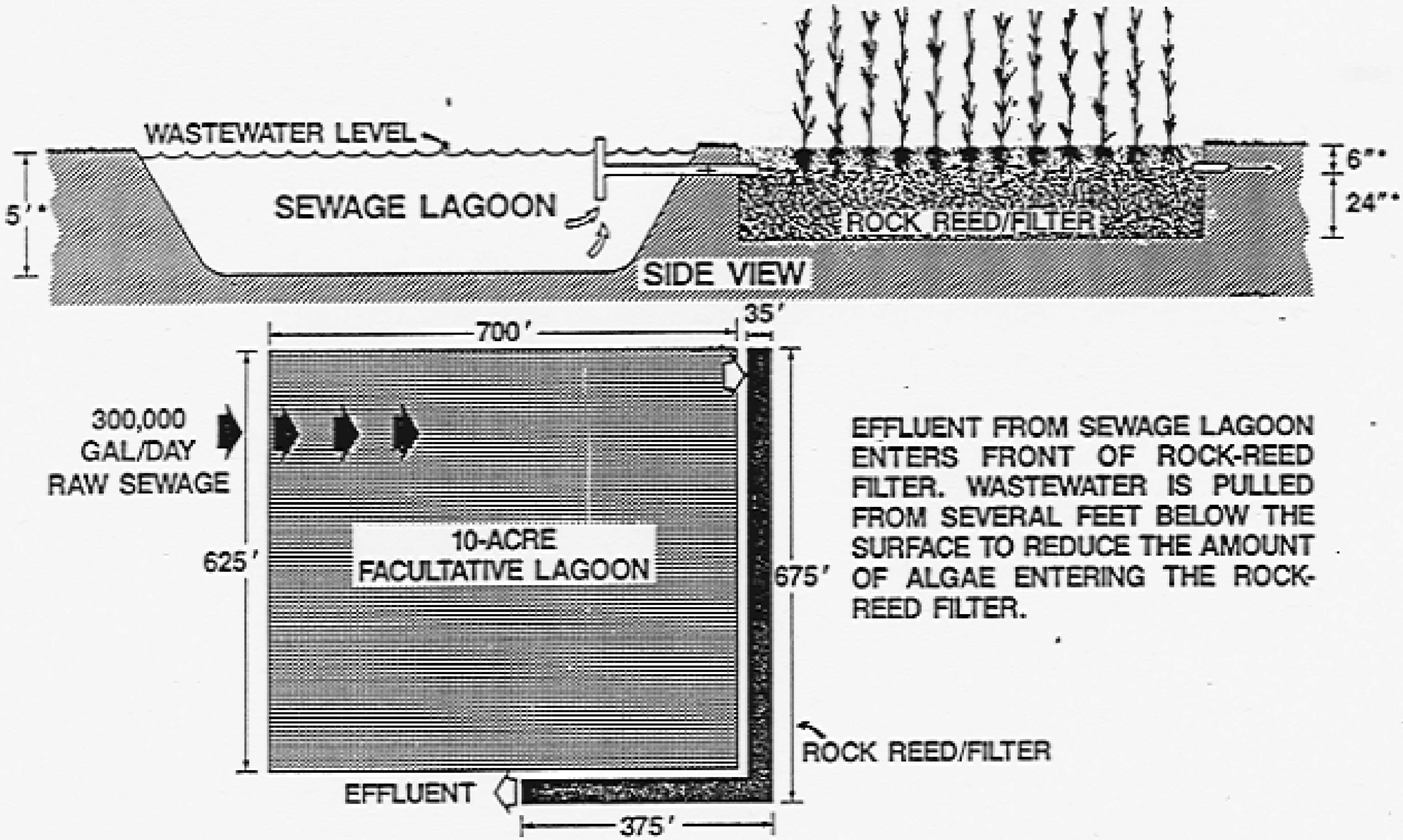
INDUSTRIAL WASTEWATER TREATMENT

The ability of microorganisms to degrade organic chemicals is well documented (23-43). Microorganisms can adapt to utilizing carbon sources from various organic chemical structures. This adaptation occurs through recruiting various genes from existing plasmids to make new plasmids. The new plasmids then code for enzymes necessary to convert the carbon sources into compounds useful for energy and cell mass synthesis (32).

Biological processing techniques have been developed which enable adapted microorganisms to be retained in the biological treatment unit or filter for periods much greater than the hydraulic retention time. Mean cell residence times of approximately 100 days can be achieved with short hydraulic retention times. This characteristic of the microbial filter process makes it very appealing for treating domestic sewage and industrial chemical wastewater.

FIGURE 5

THE USE OF ARTIFICIAL MARSHES (ROCK-REED FILTERS) TO UPGRADE SEWAGE LAGOONS TO MEET ADVANCED WASTEWATER TREATMENT STANDARDS



EFFLUENT FROM SEWAGE LAGOON ENTERS FRONT OF ROCK-REED FILTER. WASTEWATER IS PULLED FROM SEVERAL FEET BELOW THE SURFACE TO REDUCE THE AMOUNT OF ALGAE ENTERING THE ROCK-REED FILTER.

*NOT TO SCALE

The efficiency and versatility of the microbial filter process has undergone significant improvement recently with the addition of vascular aquatic plants to the system (39-41). The ability of plant roots to absorb, translocate and metabolize organic chemicals was recognized in the early 1930's. This phenomenon made possible the development of systemic pesticides and opened up a new industry. A highly biologically active artificial marsh filter can be developed by the use of plant roots and rocks. Nutrient enriched waters such as domestic sewage should be used to condition the artificial marsh filter before adding wastewater containing organic chemicals. Once the microorganisms are established on and around the plant roots, they form a symbiotic relationship with the plants and result in synergistic actions toward degradation and removal of organic chemicals from the wastewaters exposed to this filter. These reactions are very complex and are not fully understood.

During microbial degradation of the organics, certain fragments (metabolites) are produced which the plants absorb and utilize along with minerals as a food source. The microorganisms also utilize certain metabolites produced by plant roots as a food source. By each removing the others waste products, this allows a reaction to be sustained in favor of rapid removal of organics from the wastewater stream. The plants also add to the microbial filter the capability of removing toxic heavy metals and radioactive elements from the wastewater stream flowing through this artificial marsh (6,42,43). The plants remove the soluable metals and radioactive elements from the wastewater by absorption and concentration.

PLANT MANAGEMENT REQUIREMENTS

When plants are used to concentrate non-biodegradable substances and remove them from wastewater, a plant harvesting and storage process must be developed. One scheme that has been in use for over ten years at NSTL is the use of a clay-lined pit. The harvested plants containing heavy metals such as silver are stored in the clay-lined pit which has an overflow outlet back into the front end of the marsh filter. Most aquatic plants are over ninety percent water, therefore, their volume is reduced to five to ten percent of the original volume after decomposition.

There are several options available for managing plants grown in wastewater containing domestic sewage and/or industrial wastewater that contains biodegradable organics and non-toxic elements. The simplest method involves no harvesting as occurs in natural marshes. Another possible option is the controlled burning of dead plant material during late winter or early spring before the appearance of new plant shoots. The use of animals such as goats for controlled grazing of the marsh plants is an interesting alternative to burning or mechanical harvesting. This method can only be used after assurance that the plants are free of toxic chemicals.

ADVANTAGES AND DISADVANTAGES OF USING ARTIFICIAL MARSHES FOR WASTEWATER TREATMENT

The artificial marsh concept for treating and recycling wastewater is in most cases a viable alternative to conventional mechanical treatment systems.

Advantages of the artificial marsh treatment process over mechanical systems are: (1) less costly to install in most locations; (2) lower operational and maintenance cost; (3) non-technical personnel can operate and maintain; (4) more flexibility and less susceptibility to shockloading; (5) less energy required to operate, and (6) greater reliability.

The major disadvantages of the microbial-rock-plant artificial marsh wastewater treatment process are the land area required and that only limited operational and engineering design data are presently available. Some of the more critical design parameters that have been identified are rock sizes to prevent filter clogging, retention time in the filter to achieve desired treatment levels, and types of marsh plants used. An area of approximately 4 acres is required to treat one million gallons of wastewater per day.

DISCUSSION AND RECOMMENDATION

Artificial marshes come in several different configurations and are constructed in different ways. The most effective marshes for treating domestic and industrial wastewaters include rock filters and unfortunately are the most susceptible to clogging. Each filter should be designed in accordance with the receiving wastewater stream. Larger rocks should be used in the front portion of marsh filters receiving algae laden discharged water from sewage lagoons during the summer months. Marshes installed in colder climates will require a longer retention time in the filter, different types of plants, and increases land area. Different types of wastewater may also require different retention times and different types of marsh plants.

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