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# SEGREGATION AND SEPARATE TREATMENT OF BLACK AND GREY HOUSEHOLD WASTEWATERS TO FACILITATE ONSITE SURFACE DISPOSAL

by

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# SEGREGATION AND SEPARATE TREATMENT OF BLACK AND GREY HOUSEHOLD WASTEWATERS TO FACILITATE ONSITE SURFACE DISPOSAL[1]

Robert Siegrist[2]

For many years, subsurface soil disposal via the conventional septic tank soil absorption system has been the primary method for disposing of wastewater in unsewered locations. When located, designed, constructed and maintained properly, this system can provide a very suitable method of waste disposal. Unfortunately, approximately 2/3 of the total land area in the United States has soil conditions which are very poorly suited to this method of disposal (1). Mound and fill soil disposal systems were developed as an alternative for certain problem soil areas (2). But, there are many other areas where even these alternatives do not facilitate subsurface soil disposal. At present, the only widely accepted alternative for these areas is the use of a holding tank with frequent pumping and off-site disposal. However, its very high operational cost has for the most part, excluded it from serious consideration.

The lack of adequate wastewater disposal systems for problem soil areas has caused concern for public health and environmental quality, limited non-urban development, hindered rational land-use planning, and frustrated both public and private interests. Clearly, a need exists for alternative treatment systems whose applications are not dependent on site soil conditions.

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One alternative currently being evaluated at the University of Wisconsin, employs septic tank or aerobic unit pretreatment of household wastewater followed by sand filtration, disinfection and surface discharge. A detailed discussion of this alternative may be found in two recent publications (3, 4).

Another alternative which is under preliminary investigation utilizes the in-house separation of the toilet wastes (black water) and the other household wastes (grey water) to facilitate their separate treatment and disposal. This waste segregation-separate treatment concept appears to offer certain technological advantages over combined waste treatment, especially when considering surface discharge. If the black waters were removed from the liquid waste stream through use of an alternative toilet system, the remaining grey waters should be more amenable to treatment for ultimate surface disposal. This paper contains a discussion of the theory and application of waste segregation and separate treatment as a means of facilitating an onsite wastewater disposal system not dependent on site soil conditions.

## BACKGROUND

Initially the search for improved methods of on-site wastewater disposal centered largely around improving treatment and soil disposal technology. Recently, more attention has been directed toward developing methods for altering the characteristics of typical household wastewater, not only to enhance conventional disposal methods, but to facilitate the development of alternatives. Of the various alteration techniques proposed, waste segregation appears to offer the greatest potential, especially in regard to facilitating the development of an alternative treatment system not dependent on site soil conditions. To appreciate the efficacy of segregating the black and grey wastewaters for separate treatment and disposal, requires an understanding of how various pollutants are distributed between the two waste streams.

Typical Combined Wastewater

To provide perspective for subsequent discussions related to the nature of segregated wastewater, the characteristics of combined household wastewater will be examined first. Several studies have been conducted to determine the characteristics of typical household wastewater by various investigators across the country. Although the daily pollutant contributions can vary considerably at a given home and between homes, several recent studies (5, 6, 7, 8, 9, 10) indicate the average contributions shown in Table 1. It should be noted that the wastewater contribution from household garbage disposals was not included in the results presented in Table 1. It is felt that the use of a garbage disposal is not justifiable for a home employing onsite sewage disposal since it can contribute substantial quantities of pollutants which could be effectively disposed of as solid wastes (7, 9, 10).

TABLE 1. Average Pollutant Discharge in Household Wastewater[1], mass/capita/day[2]

| Study / Pollutant | Olsson (5) | Wallman (6) | Ligman (7) | Laak (8) | Bennett (9) | Siegrist (10) | Mean g/c/d | Mea mg/ |
|---|---|---|---|---|---|---|---|---|
| $BOD_5$ | 45.0 | - | 48.1 | 48.6 | 34.8 | 49.6 | 45.2 | 26 |
| Suspended Solids | 48.0 | - | 46.3 | - | 47.3 | 35.1 | 44.2 | 26 |
| Nitrogen | 12.1 | - | 16.8 | - | 7.2 | 6.1 | 10.6 | 6 |
| Phosphorus | 3.8 | - | 4.1 | - | - | 4.0 | 4.0 | 2 |
| Flow, gal/c/d | 52.1 | 52.0 | 46.0 | 41.4 | 43.7 | 36.5 | 45.3 | - |

[1]The results are for households with typical appliances excluding garbage disposals.

[2]All pollutant contributions are expressed in grams/capita/day except flow, which is in gallons/capita/day, and the mean concentration, which is in mg/l.

In addition to the chemical/physical contributions shown in Table 1, bacteriological characteristics are of interest. Since very little research has been performed on raw individual household wastewater, the bacterial contents determined in household septic tank effluent are presented (11). Although the values presented are for septic tank effluents, rather than raw wastewater, they do give an idea of the bacteriological character of typical individual household wastewater. As shown in Table 2, the quantities of indicator bacteria are consistently very high and pathogenic bacteria, as Pseudomonas aeruginosa, have commonly been isolated. In addition, results of analyses for staphylococcus aureus and salmonellae have indicated their presence in septic tank effluents, but infrequently and in much lower concentrations (Table 3).

TABLE 2. Bacteriological Quality of Household Septic Tank Effluent[1] (11), Bacteria /100 mls

| Organism | Data Points | Mean[2] | 95% Confidence Interval |
|---|---|---|---|
| Fecal Streptococci | 97 | 3800 | 2000 - 7200 |
| Fecal Coliform | 94 | 420,000 | 290,000 - 620,000 |
| Total Coliform | 91 | 3,400,000 | 2,600,000 - 4,400,000 |
| Pseudomonas Aeruginosa | 33 | 8600 | 3800 - 19,000 |
| Total Bacteria | 88 | $34 \times 10^7$ | $25 - 48 \times 10^7$ |

[1]The results are for samples from septic tank effluents at five residences.

[2]Log normalized data.

TABLE 3. Frequency of Staphylococcus Aureus and Salmonella spp. in Septic Tank Effluent (11)

| Household | Staphylococcus Aureus | | Salmonella spp. | |
|---|---|---|---|---|
| | Total Samples | Positive Samples | Total Samples | Positive Samples |
| A | 16 | 0 | 8 | 0 |
| B | 14 | 1 | 6 | 0 |
| C | 5 | 3 | 1 | 0 |
| D | 6 | 0 | 3 | 0 |
| E | 8 | 1 | 10 | 0 |
| F | 7 | 1 | 9 | 1 |
| G | 4 | 0 | - | - |
| H | 1 | 0 | 6 | 0 |
| I | 1 | 0 | 7 | 0 |
| J | 1 | 0 | 1 | 0 |
| K | - | - | 2 | 0 |
| L | - | - | 2 | 1 |
| TOTALS | 63 | 6 | 55 | 2 |
| Range of Concentrations | 10/100 ml to 1000/100 ml | | 3.4/100 ml to > 20/100 ml | |

In regard to the virological characteristics of individual household wastewater, very little data has been presented. One investigator estimated the level of viruses in raw municipal wastewater to be about 7000 PFU/liter, while another investigator reported recoveries of only 32 to 107 PFU/liter (12).

## Segregated Wastewaters

Of special interest in the context of this discussion, are the characteristics of the separated black and grey wastewater streams. The results of the characterization studies mentioned earlier (5-10) have been used to predict the division of chemical/physical pollutants between these two waste streams. The results are shown in Table 4. On the average, the grey water contributes about 65% of the flow, 70% of the phosphorus and 63% of the $BOD_5$; while the black water contributes about 61% of the suspended solids, 82% of the nitrogen and 37% of the $BOD_5$.

TABLE 4. Pollutant Division Between the Black and Grey Wastewater Streams[1]

| POLLUTANT | GREY | | | | BLACK | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean % | Range % | Mean g/c/d | Mean mg/l | Mean % | Range % | Mean g/c/d | Mean mg/l |
| $BOD_5$ | 63 | 51-80 | 28.5 | 255 | 37 | 20-49 | 16.7 | 280 |
| Suspended Solids | 39 | 23-64 | 17.2 | 155 | 61 | 36-77 | 27.0 | 450 |
| Nitrogen | 18 | 1-33 | 1.9 | 17 | 82 | 67-99 | 8.7 | 145 |
| Phosphorus | 70 | 58-86 | 2.8 | 25 | 30 | 14-42 | 1.2 | 20 |
| Flow | 65 | 53-81 | 29.4 gal/c/d | | 35 | 19-47 | 15.9 gal/c/d | |

[1]The values shown are based on the results of the studies used to compile Table 1, (Ref. 5-10). The results are average values for households with typical conventional appliances, excluding the garbage disposal.

The bacterial contents of the two waste streams are of prime importance. As mentioned in the previous section, effluents from septic tanks receiving combined household wastewater were found to consistently contain significant concentrations of indicator bacteria and the pathogen, Pseudomonas aeruginosa (Table 2). Staphylococcus aureus and salmonellae were also isolated, but only infrequently and in much lower concentrations (Table 3). Intuitively, one would expect that the great majority of these organisms in combined household wastewater are contributed in the toilet wastes, with the grey water being fairly innocuous. To evaluate this intuitive hypothesis concerning the grey water, field studies were conducted at the University of Wisconsin (10, 13). In-house samples of the wastewater produced by two key grey water events, bathing and clothes washing, were obtained from each of six households over a two-week period. Bacteriological analyses were performed for total and fecal coliforms and fecal streptococci. Details regarding the sampling and analytical procedures may be found elsewhere (10, 13).

The summarized results of the study are presented in Table 5. As shown, the results demonstrate that a wide range of indicator organisms can be expected in the raw bath and laundry wastewaters, which in turn indicates a potential for their pathogenic contamination.

TABLE 5. Selected Bacteriological Characteristics of Bath and Laundry Wastewaters (Siegrist)[1]

| Event | Organism | Samples | Mean[2] #/100 ml | Confidence Intervals[2], #/100 ml | |
|---|---|---|---|---|---|
| | | | | 95% | 99% |
| Clothes Washing[3] | Total Coliforms | 41 | 215 | 65 - 700 | 45 - 1020 |
| | Fecal Coliforms | 41 | 107 | 39 - 295 | 28 - 405 |
| | Fecal Streptococci | 41 | 77 | 27 - 220 | 19 - 305 |
| Bathing | Total Coliforms | 32 | 1810 | 710 - 4600 | 530 - 6160 |
| | Fecal Coliforms | 32 | 1210 | 450 - 3240 | 330 - 4410 |
| | Fecal Streptococci | 32 | 326 | 100 - 1050 | 70 - 1510 |

[1]The results shown are based on in-house event sampling at each of six households.

[2]Log-normalized data.

[3]Samples were obtained from the middle of the wash cycle. Samples taken from several rinse cycles also were consistently lower than the corresponding wash cycle values.

To get a better feel for the actual magnitude of this "potential," analyses were performed on several of the samples for two common pathogens, Pseudomonas aeruginosa and Staphylococcus aureus. The results as shown in Table 6, indicate a very low incidence of Pseudomonas aeruginosa and in those samples where it was isolated, the concentrations were always below 20/100 ml. Staphylococcus aureus was not isolated in any of the samples analyzed. Based on these results, the pathogenic contamination in these raw bath and laundry wastewaters would appear to be fairly insignificant.

TABLE 6. Pseudomonas aeruginosa and Staphylococcus aureus in Bath and Laundry Wastewater (Siegrist)

| Pathogen | Home | Bathing | | | Laundry | | |
|---|---|---|---|---|---|---|---|
| | | Samples | Positive Samples | Highest Value | Samples | Positive Samples | Highest Value |
| Pseudomonas aeruginosa | N | 10 | 2 | 2/100 ml | 17 | 5 | 20/100 ml |
| | R | 1 | 0 | –[1] | 4 | 0 | –[2] |
| | W | 10 | 0 | –[2] | 5 | 0 | –[2] |
| Staphylococcus aureus | N | 9 | 0 | –[3] | 17 | 0 | –[5] |
| | R | 1 | 0 | –[4] | 4 | 0 | –[5] |
| | W | 10 | 0 | –[5] | 4 | 0 | –[5] |

Below detection limit of test which was: [1]2/100 ml, [2]20/100 ml, [3]10/100 ml for 3 samples and $10^4$/100 ml for the remaining, [4]$10^4$/100 ml, [5]10/100 ml.

Since the bath and laundry are the two major household activities which possess the potential for contributing pathogenic bacteria to the grey water, the low pathogenic contamination of these wastewaters would seem to indicate a low potential for pathogenic contamination in the grey water stream as a whole. To facilitate comparison of the bacteriological characteristics of several household waste streams and provide perspective, Table 7 has been prepared. As shown, while the raw grey water is <u>not</u> innocuous, its potential for pathogenic contamination appears to be <u>substantially</u> lower than that of either the toilet wastes or combined household wastewater (Table 7).

TABLE 7. Comparison of Selected Bacteriological Characteristics in Various Household Wastewater Streams, #/100 mls

| Organism \ Effluent | Combined Septic Tank Effluent[1] | Raw Toilet Wastes[2] | Raw Grey Water[3] |
|---|---|---|---|
| Total Coliforms | 3,400,000 | 6,300,000 | 1810 |
| Fecal Coliforms | 420,000 | 5,000,000 | 1210 |
| Fecal Streptococci | 3,800 | - | 326 |
| Pseudomonas aeruginosa | 8,600 | - | 0-20 |
| Staphylococcus aureus | 10-1000 | - | 0 |

[1]Mean values from Table 2 and 3.

[2]Based on the values determined by Olsson et al. (5) as diluted in four toilet flushes of five gallons each.

[3]Based on the highest mean value determined in the bath and clothes washing sampling, Tables 5 and 6.

Very little is known about the concentration of virus in the total raw wastewater from an individual household, much less the concentration of virus in the grey and black water fractions. Based on the results of the bacteriological analyses previously described, it seems reasonable to assume that if someone in a household were shedding virus, the potential would exist for viral contamination of the grey water. As was the case with pathogenic bacteria, however, this potential is most likely very low, with the virus concentrated in the toilet waste.

In an attempt to better identify the potential for contamination of household grey water by pathogenic bacteria and virus, studies are in progress at the University of Wisconsin. The results of these studies will be summarized in a forthcoming publication (13).

SYSTEM APPLICATION

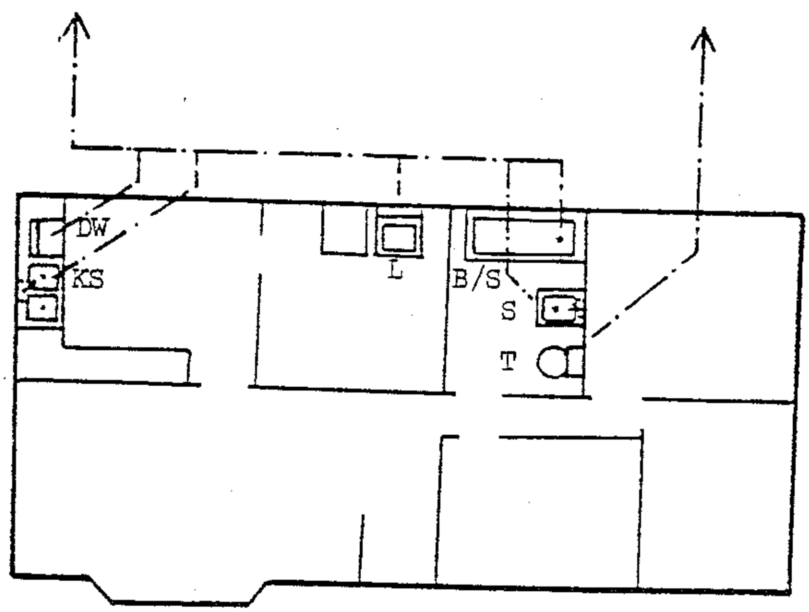
Any small-scale waste treatment system which includes surface discharge of the treated wastewaters must be reliable in producing a consistently high quality effluent to ensure protection of the public health and the environment. The point of final surface disposal, be it a stream, lake, ditch or field, ideally should dictate the effluent quality required. Regardless of the final discharge point, however, it is likely that only very low concentrations of pollutants will be tolerated.

For most applications the pollutants of concern will include $BOD_5$, suspended solids and pathogenic organisms and in many applications, nitrogen and phosphorus also. Removing quantities of these waste constituents at the source reduces the quantities to be removed in the onsite waste treatment system. This should facilitate the development of a treatment system capable of satisfying the effluent criteria for surface discharge. In addition, it would minimize the hazards in the event of a system malfunction.

The previous review of the pollutant distribution between the black and grey wastewater streams, should illustrate the efficacy of waste segregation in terms of removing pollutants from the liquid waste stream prior to treatment and disposal. As discussed in the previous section and graphically depicted in Figure 1, the black waters contain the majority of pathogenic organisms, nitrogen and suspended solids in addition to significant quantities of $BOD_5$ and phosphorus. Thus, if they were removed from the liquid waste stream through use of an alternative toilet system, the grey water should be more amenable to an alternative onsite treatment system employing surface discharge. The following sections contain a discussion of several potential methods for accomplishing this segregation and separate treatment/disposal.

FIGURE 1. Typical Distribution of Pollutants Between Black and Grey Waters

| Grey Water | | Pollutant | | Black Water |
|---|---|---|---|---|
| 65% | ← | Flow | → | 35% |
| 63% | ← | $BOD_5$ | → | 37% |
| 39% | ← | Suspended Solids | → | 61% |
| 18% | ← | Nitrogen | → | 82% |
| 70% | ← | Phosphorus | → | 30% |
| Very Low | ← | Pathogens | → | Vast Majority |



Alternative Toilet Systems.

Many alternatives to the conventional flush toilet have been proposed which provide for the segregation and separate handling of the black waters. In a recent study, over a dozen alternative toilets were identified (14). It is beyond the scope of this paper to describe all of the proposed alternative systems, much less evaluate their suitability for various applications. However, a few of the alternatives which appear to be most feasible for household use shall be discussed, including the composting, incinerating, recycle, and low-volume flush/holding tank systems. In the following pages a brief description of each of these toilet systems along with its basic principles of operation may be found. It should be noted that for the most part, the alternative toilet systems described, and various others, are still under development and/or evaluation for household use. As a result, the actual operation of a particular unit may differ somewhat from that suggested by the stated principles of operation.

Composting Toilets. These units accept the toilet wastes and commonly the garbage wastes and as the name implies, utilize the natural process of composting to affect their decomposition. Two types of composting toilets are available: those which have the point of use separated from the decomposition chamber ("separated systems"), and those which have the point of use directly attached to the chamber ("non-separated systems"). A brief discussion of each type follows.

The separated systems accept and actually rely on receiving the kitchen garbage wastes in addition to the toilet wastes. These waste materials are deposited without water into a decomposition chamber located directly below through a vertical chute from the toilet stool and possibly a second chute from the kitchen. The chamber, commonly located in the basement, usually has a sloping bottom and may be divided into several sections. The waste materials, deposited in the upper end of the chamber, are oxidized by aerobic microorganisms as they slowly move down the sloping chamber bottom. To maintain proper composting conditions, the chamber is well vented. In addition, in certain cold environments a small space heater may be required. During the composting process, any odors or vapors produced are conducted upward through a vent pipe to the roof, either naturally or with the aid of a small fan.

Upon reaching the lower end of the chamber the waste materials have been converted to a stable, humus-like material whose volume is about 10% of the original waste volume. Over time, humus accumulates at the chamber bottom and periodically, its removal is required. An access panel is provided to facilitate this. The frequency of removal varies depending on the size of the decomposition chamber, but is usually less than two or three times yearly for an average family of four. Once removed, the humus reportedly can be used as a soil amendment.

The non-separated composting toilets usually have a much smaller decomposition chamber which is attached directly to the toilet seat, the entire unit being located on the same floor. The toilet wastes are deposited directly into the decomposition chamber (garbage wastes may be added also). The wastes in the chamber are oxidized over time, again by aerobic microorganisms, to a stable, humus material. Due to the smaller decomposition chamber size, these units often times include heating elements in the chamber in an attempt to accelerate the process. As with the separated systems, the chamber is vented to ensure aerobic conditions and any odors and vapors produced are conducted through a vent pipe to the roof, either naturally or with the aid of a small fan. The accumulated humus must be removed periodically. With these units, removal is usually required yearly for a family of four. Once removed, the oxidized waste materials can reportedly be used as a soil amendment or disposed of as refuse.

Incinerating Toilets. Incinerator toilets are small self contained units which, as the name implies, utilize the process of incineration to burn the solid wastes and evaporate the liquids. Toilet wastes are deposited directly into a combustion chamber and upon closing the toilet lid or flipping a switch, incineration of the waste materials starts automatically. The incineration is usually fueled by propane/natural gas, electricity or a combination of the two and usually lasts for 10 to 15 minutes followed by a 5-minute cooling period. The cycle may be interrupted at any time and the unit used, by opening the lid. Most units are equipped with a blower and vent pipe to remove any odors and the vapors and heat produced. The incinerated waste materials, basically ashes, must be removed periodically and the unit cleaned. For a family of four, this would typically occur weekly. Once removed the ashes may be disposed of in a manner similar to that for most refuse.

Recycle Toilets. All of the recycle toilets available and under development are similar to the conventional flush toilet in that a flushing liquid is utilized to cleanse the toilet bowl and transport the waste materials. In addition, several of the systems employ a toilet fixture which is almost identical to that of the conventional. However, these systems are markedly different in that they do not utilize tap water, but instead purify and use the same fluid repeatedly (usually water or a mineral oil). The actual process used to purify the flushing medium varies considerably between systems but commonly includes separation, aeration, filtration or a combination thereof. The purification normally takes place in a treatment/storage tank installed outside the structure containing the toilet fixture. This tank is normally sized so that removal of accumulated solids is not required more than once a year. Once removed, the solids or sludge may be disposed of at a municipal treatment facility or possibly a suitable land disposal site.

Low-volume Flush Toilet/Holding Tank System. The very low-volume flush toilets are very similar to the conventional flush toilet in appearance and user operation. Fresh tap water is even used as the flushing medium. However, the very low-flush units utilize less than one gallon of water per flush. This is normally accomplished by employing compressed air or a vacuum to assist in the flushing. The smaller volume of wastes produced through use of a low flush toilet can be directed to a retention tank for periodic pumping. The pumpage from the tank can be disposed of offsite similar to the manner in which septage is handled, i.e. to a suitable land disposal site or possibly a municipal wastewater treatment facility. For a typical family of four, this servicing would be required approximately twice a year.

To facilitate a general comparison of the previously described systems, Table 8 has been prepared. In addition, a partial listing of unit manufacturers has been included in Appendix A.

The actual decision as to whether or not a given alternative toilet system can be utilized is usually subject to the approval of an appropriate state or local regulatory agency. Obviously, any system which is considered for use, should provide for (1) sanitary conditions at the point of use, (2) safe ultimate disposal of the toilet wastes, (3) reasonably low maintenance and user attention, (4) long-term user acceptance, and (5) reasonably low capital and operating costs. Unfortunately, these criteria are somewhat subjective and their interpretation will most likely vary between individuals, as well as applications. In addition, it is difficult to assess whether certain of the alternative toilets meet these criteria, since they are really still under development and/or evaluation for household use. As a result, one must be encouraged to exercise care in selecting an alternative toilet system. As development and evaluation continue and performance information is compiled, unit selection will become easier.

TABLE 8. Alternative Toilet System Characteristics[1]

| Toilet System | Similarity to Conventional | | Approximate Resource Requirements | | | | Final Product Disposal | Scheduled Maintenance |
|---|---|---|---|---|---|---|---|---|
| | Appear. | Use | Water | Power | Fuel | Other | | |
| Composting Separated | Low | Low | None | Low | None | None | Soil Amendment | Periodic Residue Removal |
| Non-Separated | Low | Low | None | Mod. | None | None | Soil Amendment | Periodic Residue Removal |
| Incinerating | Mod. | Mod. | None | Low-High | Low-High | None | Refuse | Weekly Ash Removal Periodic Unit Cleaning |
| Recycle | Mod.-High | Mod.-High | None | Low | None | Pumping | Treatment Plant or Land Disposal | Annual Servicing and Accumulated Solids Pumping |
| Low Flush/ Holding Tank | High | High | 2 qts./Use | Low | None | Pumping | Treatment Plant or Land Disposal | Semi-Annual Tank Pumping |

[1] The characteristics shown may vary considerably depending on the individual unit and/or application in question.

Grey Water Systems

In contrast to the development of alternative toilet systems, to date, there has been only limited research conducted and experience gained regarding the onsite treatment and disposal of household grey water. This is especially true when considering onsite surface discharge. However, a grey water treatment system is herein proposed which appears suitable for many applications. The system includes septic tank pretreatment followed by sand filtration and then surface disposal. Although this system has not been evaluated thoroughly, its feasibility is supported by the performance of a similar system used for treatment of combined household wastewater (3, 4, 15).

A schematic of the proposed grey water treatment system is shown in Figure 2 and a description of the individual components is given in the following pages.

The grey water generated within the home is collected in conventional plumbing and transported to a 750 or 1000 gallon septic tank. The effluent from the septic tank flows into a small wet well where either a dosing siphon or a 1/3-1/2 hp submersible pump intermittently applies the effluent to a sand filter. The filter consists of 30 inches of sand (approximate effective size and uniformity coefficient of 0.4 and 3.0, respectively) overlying 8 inches of supporting pea gravel. The surface area of the filter is established so that the average daily loading rate will be approximately 5 gallon/day/$ft^2$. With this loading rate, the surface area required for a filter serving a typical family of four would be 25 $ft^2$ (based on a per capita grey water flow of 32 gallons/day). A schematic of a pair of filters is shown in Figure 3. The effluent from the filter is collected in perforated pipes laid in the pea gravel and then transported to a small wet well for holding prior to surface disposal. Depending on site conditions, especially topography and distance to the discharge point, the treated wastewater will be transported by gravity or with the aid of a 1/3-hp

FIGURE 2. Grey Water Treatment System

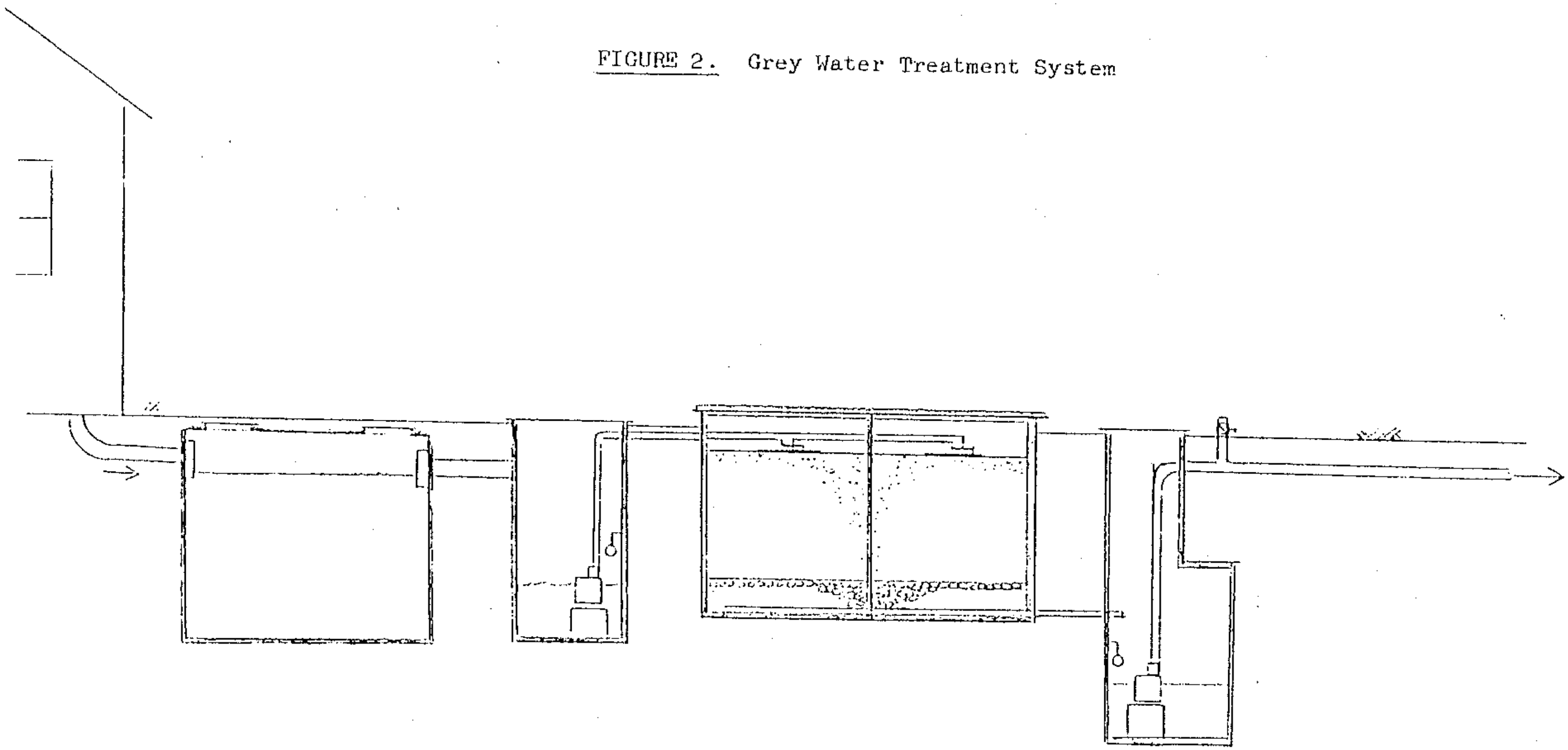
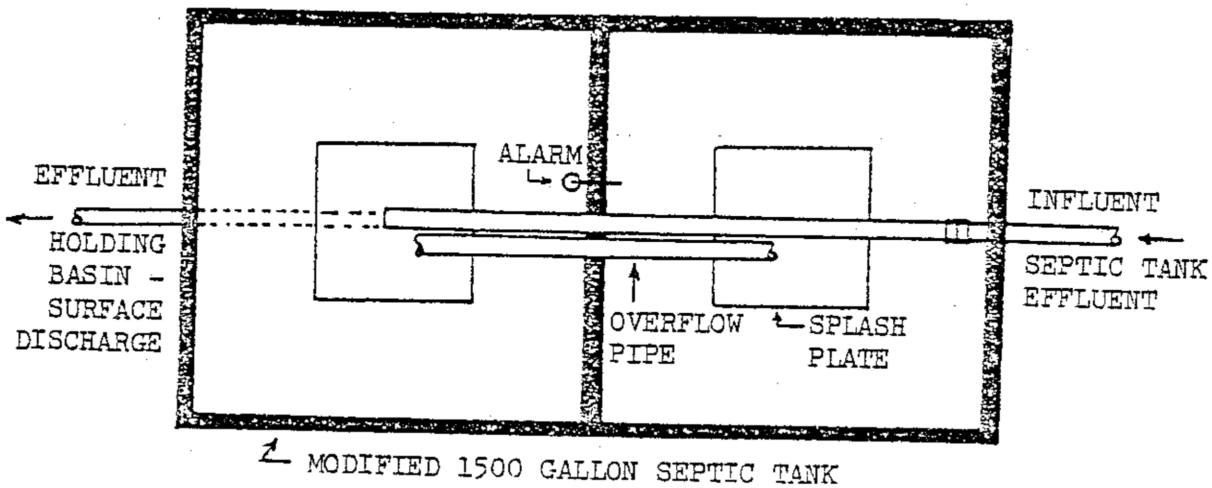
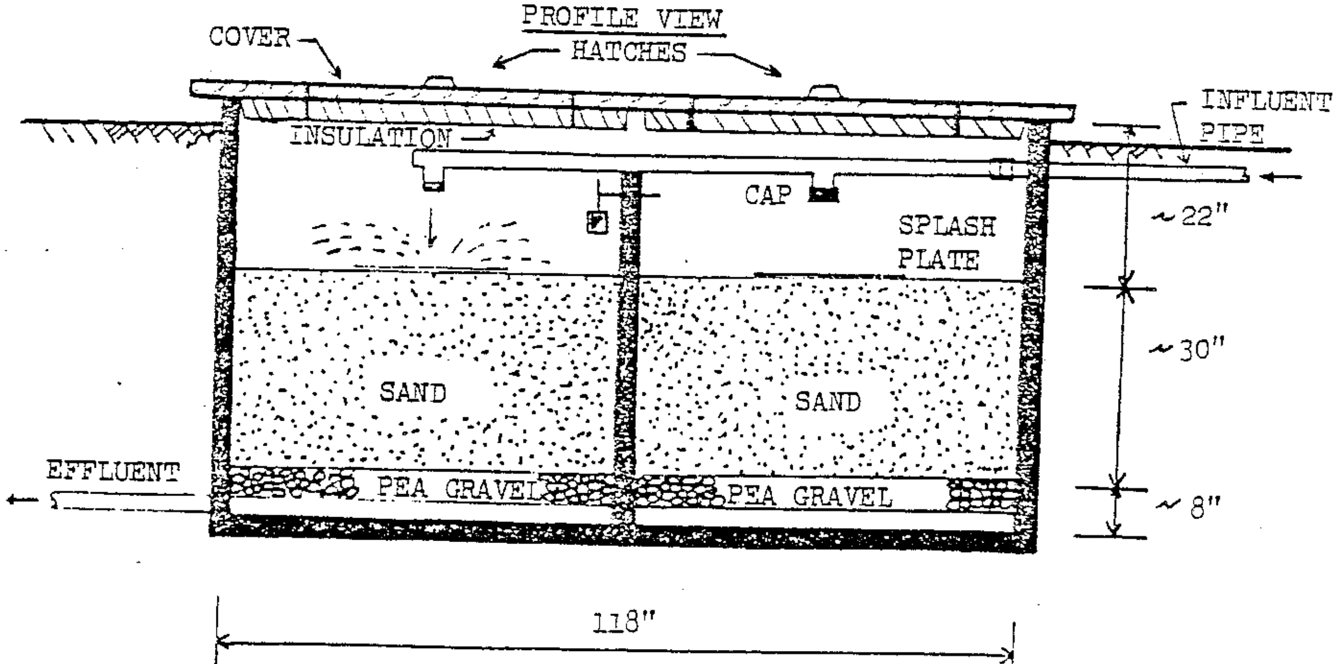


FIGURE 3. Schematic of a Sand Filter for Treatment of Household Grey Water

PLAN VIEW




PROFILE VIEW




APPROXIMATE SCALE: 1" = 5'

submersible pump. The surface discharge point will depend on the site conditions of individual applications, but could include irrigation methods or surface water disposal for individual households or clusters thereof.

The effectiveness of this type of sand filtration after septic tank pretreatment has been demonstrated for combined household wastewater (3, 4, 15, 16). Based on several years of monitoring field installations treating combined wastewater, Sauer has demonstrated significant reductions of $BOD_5$, suspended solids and indicator organisms with average effluent qualities of 4-10 mg/l for $BOD_5$, 6-11 mg/l for suspended solids, and 1.3-18 x $10^3$ bacteria/100 ml for fecal coliforms. The nitrogen and phosphorus were oxidized, but only minor quantities were removed (3). Similar results and observations have also been made in the laboratory (16). Based on the results of these field and laboratory studies, the average reductions and effluent qualities shown in Table 9 are representative for sand filtration of the effluent from a septic tank receiving combined wastewater.

As shown in Table 9, sand filtration after septic tank pretreatment of combined wastewater produces a fairly high quality effluent, containing low concentrations of chemical/physical pollutants and indicator bacteria. With a knowledge of the pollutant contribution of typical grey water (Table 4) as compared to combined wastewater (Table 1), it seems reasonable to expect at least an equal, and possibly higher quality effluent from a similar system treating just grey water. The magnitude of the $BOD_5$, and phosphorus concentrations would most likely be similar to that shown in Table 8, but the pollutant mass would be lower due to a decreased influent mass. A considerably lower concentration and total mass of suspended solids and nitrogen should be realized due to the reduced influent strength of the grey waters.

**TABLE 9.** Pollutant Reductions Through Sand Filtration After Septic Tank Pretreatment of Combined Household Wastewater[1] - 5 gallon/day/ft$^2$

| Parameter | Laboratory (16) | | | Field (15)[2] | | |
|---|---|---|---|---|---|---|
| | Septic Tank Effluent | Sand Filter Effluent | % Reduction | Septic Tank Effluent | Sand Filter Effluent | % Reduction |
| $BOD_5$ | 53 mgl | 3 mgl | 94% | 123 mgl | 9 mgl | 93% |
| Suspended Solids | - | - | - | 48 | 8 | 79 |
| Volatile Suspended Solids | 18 | 5 | 76 | 37 | 5 | 87 |
| Nitrogen | 57 | 47 | 17 | 24 | 24 | 0 |
| Phosphorus | 38 | 26 | 32 | 10 | 9 | 10 |
| Fecal Coliforms | $1 \times 10^5$ | $1.9 \times 10^2$ | 2-3 logs | $6 \times 10^5$ | $7 \times 10^2$ | 2-3 logs |
| Pseudomonas Aeruginosa | 34 | 1 | 1-2 logs | $1.3 \times 10^4$ | $2.7 \times 10^1$ | 2-3 logs |

[1]These results are based on a 5 gallon/day/ft$^2$ average loading rate and filtration through two feet of sand with an approximate effective size of 0.3 and a uniformity coefficient of 4.0.

[2]The values presented for Pseudomonas aeruginosa are from Ref. 17.

In addition to the chemical/physical pollutants, of prime importance is the bacterial concentrations expected in the effluent. Based on a much lower influent concentration, the coliform and pathogenic bacteria concentrations in the effluent should be fairly insignificant. In addition, preliminary laboratory research suggests that this type of sand filtration should also remove the small quantities of virus which might enter the grey water stream, if they were not removed in the septic tank first (18).

For many applications, the effluent quality that the proposed grey water treatment system appears capable of producing, should be suitable for surface disposal. However, the anticipated nitrogen and phosphorus concentrations may be too high for certain applications. In these cases, further nutrient removal would be necessary. The phosphorus concentration could probably be significantly reduced through the use of non-phosphate detergents. In addition, near-complete removal of both nitrogen and phosphorus may be possible through the use of simple ion-exchange cartridges inserted in the basic flow sheet at appropriate locations. Research is currently on-going at the University of Wisconsin to develop effective onsite nutrient removal processes.

Continuous system operation and production of a high quality effluent will require a certain amount of maintenance to the sand filters. Based on the results of sand filtration of combined wastewater, the 5 gallon/day/ft$^2$ loading rate specified will result in clogging of the sand after several months of continuous operation, at which time maintenance will be required. To facilitate this maintenance, the filter surface is readily accessible from the ground surface via insulated removable covers (Figure 3). The maintenance consists of raking the sand surface and then removing the filter from operation for at least one month. To enable this resting period, a second identical filter is initially installed in parallel with the first. Thus, after approximately three months of operation with one filter, the waste flow would be directed to the second filter and the first filter's sand surface would be raked and the filter rested for three months at which time the process would be repeated. In addition to the raking, periodic replacement (once per year) of the top 4 inches of sand appears necessary (3, 4).

It should be emphasized that these predicted effluent qualities and maintenance requirements have been based on the performance evaluations of small scale treatment systems receiving combined wastewater. In an attempt to confirm the previous extrapolations and predictions, laboratory studies are ongoing at the University of Wisconsin at a SSWMP research facility. Although the laboratory studies will provide certain valuable information, there remains a need for the experimentation and evaluation of this and other promising grey water treatment systems under actual field conditions. To facilitate this, a segregated waste treatment research facility is scheduled for construction in June, 1977, by the University of Wisconsin at a nearby three-bedroom home. Subsequent investigations will be conducted to develop and evaluate the segregated treatment/disposal system concept with special emphasis placed on developing methods for treatment and surface disposal of the grey water fraction.

The ultimate decision as to whether surface discharge of an effluent, such as that produced by the proposed grey water treatment system, will be allowed, will rest with the appropriate regulatory agency for a given location. If approved, the successful use of this type of system will depend on ensuring that the system is inspected and maintained properly. To facilitate this, some type of institutional supervision, such as a sanitary district, will most likely be required. A detailed discussion of various institutional alternatives has been outlined by Stewart (19).

Example System

A segregated waste treatment system which appears very promising and is scheduled for evaluation at the University of Wisconsin is shown in Figure 4. The system utilizes a low-volume flush toilet connected to a 1500 gallon holding tank for semi-annual pumping and off-site disposal of the black waters. The grey waters are treated for ultimate surface disposal utilizing the previously described septic tank-sand filter system (certain applications may require further nutrient removal).

SYSTEM COSTS

The cost of a segregated waste handling system for a household would vary considerably depending on several factors, including the number of residents, the type of dwelling (seasonal or year-round), the alternative toilet system selected, the availability of a suitable sand for the sand filters, labor costs for the required maintenance, and the cost for nutrient removal if required. As a result, it is difficult to accurately estimate the system costs for a given application. However, to further illustrate the feasibility of segregated waste treatment, the estimated costs for the example system described in the previous section have been compiled in Table 10. In preparing these estimates it was assumed that the system would serve a family of four in a year-round home and a suitable sand for the sand filters and a suitable disposal site for the segregated toilet wastes were available. It was also assumed that an individual would be paid to perform system maintenance and that further nutrient removal would not be required.

As shown in Table 10, the capital costs for the system were estimated at $2900 with an annual operating cost of $154. The costs do not include unscheduled maintenance and repair costs. Also not included is the cost of

FIGURE 4. Example Segregated Waste Treatment System

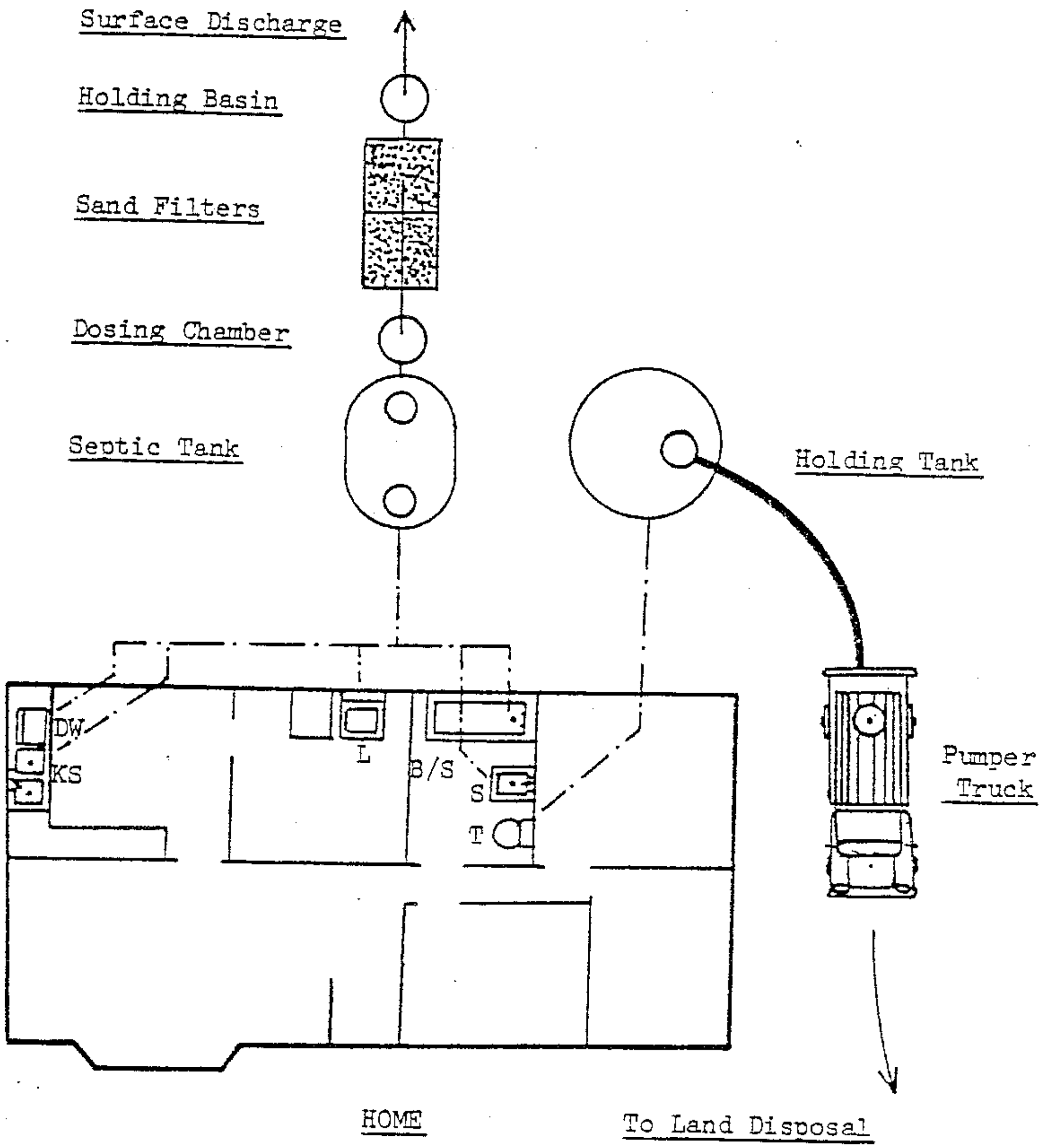


TABLE 10. Estimated Costs for an Example Segregated Treatment System[1]

| Item | Capital Costs | Operating Costs |
|---|---|---|
| Toilet System | | |
| Low Flush Toilet and Ancillary Parts | $ 500 | $2.30/year |
| 1500 gallon Holding Tank | $ 500 | $75/year[2] |
| Greywater System | | |
| 750 gallon Septic Tank | $ 350 | $10/year[3] |
| Dosing Chamber<br>3' diam. x 6' wet well, 1/2-hp submersible pump with alarm | $ 350 | $3/year |
| Sand Filters<br>2 filters with covers - 25 $ft^2$ each | $ 850 | $60/year[4] |
| Discharge Basin<br>4' diam. x 6' wet well, 1/3-hp pump if needed, hose | $ 350 | $3/year |
| TOTALS | $2900 | $154/year |

[1]For a typical family of four in a year-round home.

[2]Based on 2 pumpings/year at 2.5¢/gallon.

[3]Based on 1 pumping every 3 years at which time dosing chamber would be pumped also.

[4]Based on a site visit every 3 months to switch flow to the other filter and rake sand surface (3 x 2 hr/visit x $5/hr = $30) plus one visit to replace top 4" of sand (1 x 3 hr/visit x $5/hr + $15 for sand = $30).

an effluent sampling program. If required, sampling costs could run up to $20 or more per month. However, partially offsetting these costs, and also omitted from Table 10, are the savings which would result with reduced water consumption. It should be noted that the estimated costs shown in Table 10 are felt to be somewhat conservative. In addition, the costs most likely could be reduced significantly if the waste treatment facilities and their maintenance were provided for several individual homes or a cluster of homes by a sanitary district or the like.

A capital cost of $2900 and an annual operating cost of $154 for this example segregated system are somewhat higher than those for a conventional septic tank-soil absorption system. However, where site soil conditions prohibit subsurface soil disposal, the conventional system is not a viable alternative. The only alternative commonly available for these areas is the holding tank. The proposed combined waste sand filter system with disinfection referred to earlier may become another alternative (3, 4). To facilitate a comparison of these three alternative systems, Table 11 has been prepared. It must be emphasized that the figures shown are estimates.

TABLE 11. Alternative Disposal System Cost Comparison

| System | Approximate Capital Cost | Approximate Operating Cost |
|---|---|---|
| Segregated Waste Treatment (Table 10) | $2900 | $154/year |
| Combined Waste Holding Tank (3) | 445 | 1825 |
| Sand Filter System For Combined Wastewater (4) | 3050 | 154 |

NOTE: These costs are estimates and may vary considerably depending on the application.

As shown in Table 11, the example segregated waste treatment system is very cost-effective when compared to the combined waste holding tank. When compared to the proposed combined waste sand filter system it appears only slightly cost-effective. However, segregated waste treatment becomes more attractive and most likely, more cost-effective, when one considers that its use should result in (1) a lower effluent pollutant concentration and mass, (2) a reduced potential for pathogenic contamination in the effluent to be discharged, especially in the event of a system malfunction, (3) conservation of water resources and (4) a potential for recycling valuable nutrients to the soil in a beneficial manner.

SUMMARY

Many areas of the country have site soil conditions which prohibit the use of the conventional septic tank-soil absorption system for onsite wastewater disposal. A need exists for an alternative disposal system not dependent on site soil conditions. The use of in-house segregation of black and grey wastewaters followed by separate treatment has been reviewed as a means of facilitating such an alternative.

Various alternative toilet systems are available which provide for segregation and separate treatment of the black waters, including composting, incinerating, water recycle, mineral oil recycle, and low volume flush/holding tank systems. Very little information has been gathered regarding grey water treatment and surface disposal. However, a system has been proposed which includes sand filtration after septic tank pretreatment. The effluent from the sand filter should be of a quality suitable for surface disposal in many applications (certain applications may require additional nutrient removal).

The success of a segregated waste treatment system employing surface disposal will depend on proper maintenance being performed regularly. A suitable method of ensuring this would most likely involve some form of institutional supervision.

The cost for a segregated waste treatment system can vary considerably depending on several factors. For a family of four in a year-round home, the costs for an example segregated system employing a septic tank-sand filter system for the grey water and a very low flush toilet connected to a holding tank for the black water were estimated to include a capital cost of $2900 with an annual operating cost of $154 (excluding unscheduled maintenance costs and sampling costs). This system appears to be cost-effective when compared to a combined waste holding tank or sand filter/disinfection system.

It is recommended that a few segregated waste treatment systems as described herein be installed at private residences under experimental approvals. Evaluation of these systems under actual field conditions will provide valuable information regarding system performance, acceptability, maintenance requirements, and system costs. This type of information is necessary to establish the feasibility demonstrated in this paper.

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# APPENDIX A

## Partial Listing of Alternative Toilet System Manufacturers[1]

A. Composting Toilets

1. "Clivus Multrum"
   Clivus Multrum USA
   14A Eliot Street
   Cambridge, MA 02138
   617/491-5821

2. "Toa Throne"
   Enviroscope, Inc.
   P.O. Box 752
   Corona del Mar, CA 92625
   714/673-7774

3. "Ecolet"
   Recreation Ecology Conservation
   9800 West Bluemound Road
   Milwaukee, WI 53226

4. "Biu-Let"
   Bio-Utility Systems, Inc.
   P.O. Box 135
   Narberth, PA 19072
   215/664-6238

5. "Mull-Toa"
   Biomat Enterprises
   739 2nd Street
   Coeur d' Alene, ID 83814

B. Incinerating Toilets

1. "Little John"
   Sierra Sales
   2637 East 3900 South
   Salt Lake City, UT 84117

2. "Destroilet"
   LaMere Industries, Inc.
   Walworth, WI 53184
   414/275-2171

B. (continued)

3. "Incinolet"
   Research Products Mfg. Co.
   2639 Andjon Drive
   Dallas, TX 75220
   214/358-4238

4. "Incinomode"
   Incinomode Sales Co.
   P.O. Box 879
   Sherman, TX 75090
   214/892-6137

C. Recycle Toilets

1. "Magic Flush"
   Monogram Industries, Inc.
   3226 Thatcher Avenue
   Venice, CA 90291
   213/870-8772

2. "Sarmax"
   Sarmax Corporation
   2207 South Colby Avenue
   Los Angeles, CA 90064

3. "Cycle-Let"
   Thetford Corporation
   P.O. Box 1285
   Ann Arbor, MI 48106
   313/769-6000

D. Very Low-Flush Toilets

1. "Low Flush Toilet"
   Microphor, Inc.
   P.O. Box 490
   452 East Hill Road
   Willits, CA 95490
   707/459-5563

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[1] The inclusion or lack of any product in the above listing does not constitute endorsement or lack thereof by the author or the Small Scale Waste Management Project.

D. (continued)

2. "Envirovac"
   Enviro-West Sales Company
   P.O. Box 8880
   Stockton, CA 95208
   209/478-1137

3. "Dinky-Flush"
   Enviroscope, Inc.
   P.O. Box 752
   Corona del Mar, CA 92625
   714/673-7774

4. "Meanflusher"
   Aquasaver, Inc.
   6701 Fordcrest Road
   Baltimore, MD 21237
   301/483-1331