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Project Summary

Field Investigation of Biological Toilet Systems and Grey Water Treatment

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Operational characteristics and overall acceptability were determined for popular models of biological toilets and a few select grey water systems. A field observation scheme was devised to take advantage of in-use sites throughout the State of California. Field performance was recorded monthly on forms developed to record site conditions such as pile temperatures, odors, and vector observations. Samples of the decomposition chamber pile and the end products were taken for laboratory analyses that included both physical and microbiological parameters. Grey water influent and effluent were also analyzed.

A health risk assessment was performed concurrently using environmental health experts to estimate the probability of a significant failure for a particular onsite waste treatment and disposal system. The health experts used an objective decision-making technique that may be used by regulatory officials to evaluate new technologies where there is an absence of definitive test information. This assessment results in a probability that is expressed in relation to the estimated risk of a known system, the septic tank/soil absorption system.

Model frameworks for education and surveillance monitoring are presented. Since the user may need guidance during siting and operation and in the event of system failures, third-party management is strongly advised.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study was undertaken to assess performance characteristics, operation and maintenance problems, and health risks for seven types of non-water-carriage toilets and associated grey water treatment systems. The biological toilet systems assessed through field studies included home-built and commercially available designs. Grey water treatment systems were generally variable in design and were essentially those associated with the biological toilet systems chosen for study.

The health risk assessment technique used in the study relied on the judgment of two tiers of experts in the field of public health to assess the relative risk of an unknown system compared with a known system performing under similar conditions.

The study was initiated to address the potential public health problems posed by the increasing popularity of biological toilets and grey water treatment and disposal systems among ecologically concerned individuals in California and elsewhere in the United States.

Experimental Procedures

The site selection process began in February 1978 when all local directors of environmental health in California's 58 counties were contacted and invited to participate. Systems were selected in 10 counties, and monitoring was completed in the following 8: Calaveras, Humboldt, Kern, Marin, Mendocino, Monterey, Nevada, and Sonoma. An effort was made to obtain representative systems in as many varying environmental and physical situations as possible, but all sites and units were to meet the following criteria:

1. Units were officially recognized and in compliance with existing local requirements of county health departments and/or local regulatory bodies.
2. Units were slated for year-round use.
3. Occupants were willing to allow a year of unit monitoring.
4. County health officials and site owners agreed on the liability and confidentiality of the study.

The units selected under these criteria were subject to monthly visits by the field staff, who were either county health sanitarians or project staff from the Department of Health Services (DOHS). As the study progressed, the number of units monitored monthly varied. This variation resulted from site inaccessibility (especially during winter months), withdrawal of site owners from the study, absence of occupants on the day of inspection, inconsistent or seasonal use of units by the occupants, discontinuation of unit use during change of occupants, or failure of the field investigator to perform.

The most rigorous sampling took place between August 1979 and June 1980, when laboratory services were available to the project. Six units in Marin County were added in August 1979, and another three units in Calaveras County were added in November 1979. The type of laboratory work ordered for each site was predetermined in an effort to develop information about all system types. Analytical results were generally not available to project staff for 3 to 5 months after sampling and thus did not influence choices until the last few months, when an effort was made to follow up earlier findings. Table 1 summarizes the types and number of systems examined during the data collection phase.

The objective of the field sampling and monitoring work was to obtain as much information as possible on the operation and performance of the selected systems and on the biological, physical, and chemical aspects of the stored excreta solids, liquid, and grey water collection and treatment over a 12-month period (i.e., systems' performance over the four seasons). No attempt was made to control the amount of usage of the units by the occupants or to influence the users' decisions about operating and maintenance practices.

All persons involved in the routine sampling and monitoring were individually instructed on their first site visit by the field biologist and/or the project director to standardize the data collection activities as much as possible. To facilitate accurate and uniform recording of observations and data at each site visit, personnel were provided with written instructions and a field survey form designed by project staff.

Table 1. *Systems Examined from February 1979 through June 1980*

Type of Toilet	*No. Examined*
Waterless Toilets:	
Large, sloped fiberglass toilets	*8*
Large, sloped plastic toilets	*3*
Box-like humus toilet with topping bar	*4*
Box-like humus toilet with rotor	*4*
Vault privy	*5*
Pit privy	*4*
Drum toilet	*4*
Total	*32*
Grey Water Systems:	
Septic tank	*1*
Proprietary settling tank	*2*
Single medium filter	*1*
Dual media filter	*2*
No treatment	*3*
Total	*9*

Data and Sample Collection from Waterless Toilets

Observation of Site and Unit Conditions

Upon arriving at the site, the field investigators noted wind direction and speed. Moving upwind toward the unit, they recorded any odor associated with the toilets at distances of 100 and 50 ft from the toilet vent stack and at the residence. Distinction was made between hydrogen sulfide and ammonia odors. The investigators then interviewed the occupants concerning general and specific details of the unit operation, problems, and extent of use. Entering the bathroom or privy house, they noted the presence of any odor at the toilet port and looked for signs of excessive numbers of flies or other insects in the room.

At the vault of the unit, investigators recorded signs of spillage, leakage, vector invasion, and odors. The access port was opened, and the inside of the vault was examined by flashlight for arthropods. Odors within the vault were noted along with distribution of accumulated solids and liquids, leaks, structural problems, etc.

Temperatures were taken at the center and at the edge of the solids pile, each at one-half the depth of the pile. In units with separation of fresh and decomposed solids, temperatures were taken in each pile. For units with heating coils, an additional reading was made near the coil.

To determine solids pH in the field, investigators used non-bleeding ColorpHast* indicator strips with pH ranges of 4.0 to 7.0 and 6.5 to 10.0. The status of solids decomposition was described based on particle size and uniformity, color, and distribution of moisture.

Before closing the vault, investigators took samples of solids for submission to the Berkeley laboratories of the DOHS, and they replaced the exposed sticky fly tapes and cockroach traps with new ones.

Observations and Sampling of Arthropods

During each site visit, investigators collected representative specimens of insects, spiders, mites, and other arthropods associated with the units. Flying insects were taken with an insect net. Arthropods crawling on the solids and vault walls were picked up with forceps or a camel's hair artist's brush moistened with alcohol. The presence of mites or other arthropods on or in the immediate area of the toilet seat or kitchen port (if installed) was determined by swabbing these ports with a white cotton flannel mitten.

The occurrence of flying insects during the previous month was determined by hanging sticky fly tape in the vault at a location out of the way of fouling. To detect the presence of cockroaches, a cockroach sticky trap was placed in a corner of the vault.

Samples of solids for arthropod extraction were taken from both the fresher pile in the vault and from the decomposed pile in the removal chamber if present. Each of these samples was a composite of four subsamples taken at the edge, center, and intermediate levels in the pile; the total sample amounted to approximately 1L.

Sample Collection for Basic Laboratory and Pathogen Analyses

Samples of solids for the various microbiological, physical, and chemical analyses were also taken from the vaults with a plastic-bag-lined scoop.

The areas from which samples were selected in the solids mass of fresh material, intermediate-aged material, and finished (decomposed) material varied with the specific analysis needs of the unit being sampled.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Leachate accumulation in the vaults was sampled by suction using a plastic turkey baster. Samples for microbiological tests were submitted in sterile 4-oz plastic bottles containing sodium thiosulfate as a dechlorinating agent. Samples for physical and chemical analyses were put into a clean 1/2-gal plastic bottle.

Data and Sample Collection from Grey Water Systems

At sites of grey water systems, investigators were to examine the immediate area for signs of leakage and overflow resulting from surge loading of the treatment unit. The presence and absence of odors and insects, especially mosquitoes, were noted. Upon opening the access port, investigators were to observe and report degrees of scum layer and settled solids buildup. Disposal areas were not routinely subjected to observation. Water samples were removed from the treatment unit using the same methods described for leachates. In the systems where grey water was treated, grab samples of both the influent and the effluent were taken.

Sample Storage and Transport

All field-collected samples were shipped to the DOHS laboratories in Berkeley in 32- × 20- × 14-in. insulated boxes. The samples rested on four blue ice packs held in place with covers of 4-in.-thick flexible foam cut to fit the boxes. Most shipments were made by Greyhound Bus within the 30-hr period specified by the laboratories for uniform microbiological analyses. Upon arrival at the Berkeley facility, any samples to be composited for the basic laboratory and pathogen analyses were well mixed under a hood, and aliquots were transferred to separate containers for the bacterial, viral, and parasite screens, as required. Temperatures of the sample were not taken upon arrival at the laboratory, but with few exceptions, the blue ice packs were still partially frozen, and the samples were thoroughly cooled.

Specific analytical methods for vector extraction, identification of arthropods, coliform assays, bacteria and parasite screens, parasite confirmation and viability determination, and virus assays are detailed in the full report. Physical and chemical analyses were performed according to U.S. Environmental Protection Agency and Standard Methods.

Risk Assessment Procedure

Risk assessment was performed by the probability matrix technique (PMT), which required two groups of health experts. The first group delineated health problems that might be associated with a given process and estimated the probability of their occurrence. The second group judged the severity of the problems delineated by the first group.

Members of the first group included bacteriologists, virologists, parasitologists, entomologists, sanitary engineers, and similar professionals. They were instructed to make judgments on the probability of problem occurrence and to place a value on the probability using a linear scale of zero to one. In such a scale, values of less than 0.5 indicate that the problem is not likely to occur.

Members of the second group were all physicians who were directed to make judgments concerning the severity of the problems named by the first group. Relative severity was ranked from 0 to 100, with 100 being the most severe and 0 the least. Relative judgments about the severity of a problem were made in relation to the other problems being considered and not to some absolute level of severity. The severity judgments were medical opinions based on collective knowledge of the life expectancy, degree of disability, and treatment effectiveness associated with the public health problems considered.

Results and Conclusions

Evidence suggested that performance of the biological toilets varied from mere storage of human excrement to partially successful decomposition of organics and/or reduction of microbiological hazards. The physical presence of solids at the final chamber of a toilet system had no bearing on whether or not treatment had occurred. The rate at which excrement moved through a system depended solely on system capacity and rate of usage. In addition, the physical appearance and odor characteristics were not reliable indicators of the biological degradation process.

Most of the system users were advocates of alternative technology, yet they were generally unable to make their systems work satisfactorily. Few of these systems displayed any significant evidence of biological composting during 17 months of observation. The systems repeatedly showed evidence of conditions unfavorable for the occurrence of biological composting—for example, inadequate use of bulking agent, too much moisture, anaerobic conditions, insect vectors, and ambient temperatures. The users were generally not well informed about the particular sensitivities of their systems to improper operating procedures. Since a majority of the users were unwilling and/or unable to perform recommended operation and maintenance procedures, it is unclear whether any of the toilet systems studied were capable of acceptable performance.

Problem Areas Identified

The following are apparent problem areas identified with the proprietary toilet units studied:

1. Small or awkwardly placed openings limited physical access to the stored excrement and either prevented or hindered the users from performing routine maintenance.
2. Existing internal structural design features or mechanisms intended to mix and/or aerate solids (e.g., slanted chamber bottom or internal rotors) failed to do so.
3. Some of the proprietary devices suffered structural failures such as topping bar handle breakage under normal use, air baffle collapse under the weight of the excrement pile, metal fastener corrosion, inefficient latches, leaking holding chamber design, and other construction defects.
4. Electrical components such as heating elements malfunctioned and/or did not perform as intended.
5. Venting systems used in the studied units could not maintain aerobic conditions within the excrement pile, nor could they mitigate excessive moisture.
6. Stored excrement attracted and harbored insects even though the units were reportedly designed to prevent this problem.
7. The manufacturer's instructions to the user were not always available in English. When instructions were available, they uniformly lacked information necessary to understand the degradation process and often contained unsubstantiated and misleading information about the quality and safety of the end products.

Problem areas identified with homeowner-built toilet units are as follows:

1. Poor siting allowed the excrement chamber to become inundated with surface and/or storm runoff. Some subsurface excrement chambers were flooded by a rising groundwater table during wet weather.
2. Inadequate or missing seals and/or screens over all openings allowed insect and rodent vector access to the excrement pile.
3. Cumbersome access doors hindered vault owners during operation and maintenance, and the lack of access to drum contents prevented user maintenance activity.
4. Uncoated drums frequently corroded.
5. When the recommended scissor-jack arrangement was not used to position the drum, full drums were difficult to remove for ultimate disposal.

Most of the grey water treatment systems studied also failed to perform their functions successfully. Analytical work performed during this investigation demonstrated that individual households produced highly variable grey water of a quality similar to raw domestic sewage. Merely separating toilet wastes from the remainder of the household waste stream does not insure personal or public safety. Both clothes washing and bathing activities produced a wide range of indicator organisms. The major portion of coliforms detected were of fecal origin. None of the treatment and/or segregation schemes resulted in a reduction of microbiological hazards or a discernible wastewater treatment. Only one treatment scheme (involving a series of settling tanks) resulted in consistent removal of particulate matter.

Nearly all reuse schemes involved seasonal irrigation of landscape and/or food crops, but most were used year-round and had no provisions for ultimate disposal of poor-quality grey water and surge loads or for storage when use was contraindicated by wet weather. Homeowners did not establish a routine program for operating and maintaining their systems. They were generally aware of them only when malfunctions or problems occurred, and even then they did not place a high priority on resolving the matter.

Health Risks

The judgments made by environmental health experts indicate that the risk of a public health problem occurring in a septic tank/soil absorption system during the lifetime of the system is 1 chance in 500,000. The public health risk associated with the various combined black and grey water disposal systems ranged from 1 chance in 30,000 (for true composting, mouldering, and buried drum toilet waste with landscape-disposed grey water) to 1 in 2,300 (for drum toilet waste and grey water disposed on food crops). Systems were assigned smaller health risks when they did not involve food crops. For example, the risk associated with true composting systems in which solids are buried and grey water is used for landscape irrigation was 1 in 30,000, whereas the risk was 1 in 7,000 when grey water was applied to food crops (a fourfold increase of risk). Numerical values are relative only, but they are useful for comparing different systems.

System maintenance potentially increased the health risk to individual users, but differences in the level of system maintenance would have a limited effect on risk to the community's health, depending on population and system density.

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***Steven W. Hathaway** and **James F. Kreissl** are the EPA Project Officers (see below).*
The complete report, entitled "Field Investigation of Biological Toilet Systems and Grey Water Treatment," (Order No. PB 86-234 648/AS; Cost: $22.95, subject to change) will be available only from:
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