Household Greywater Systems

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The "Mulch Maker " Wood Chip Greywater System

The wood chip composting greywater system was developed by Doug Clayton here at Gap Mountain Permaculture, and has been running for two years now. The system is intended to "dispose of greywater in a safe and sanitary manner and to recycle this water to a second productive use," which in this case is to hasten the decomposition of wood chip piles so the resulting humus can be used as a soil amendment. He developed this system because his research and decision was to avoid the use of greywater for irrigation because of the salting problems had by others he had talked with. It consists of a 100-gallon grease trap, followed by a 70-gallon tank with a dosing siphon, a simple switch mechanism and two 40-foot long piles of wood chips, used alternately, with PVC perforated pipe suspended in the middle of them (See Sketch 1).

The grease trap allows the greywater to cool off so that the oils and grease can float to the surface and some solids can settle to the bottom (essentially a mini septic tank). Doug built his tanks out of fiberglass and resin for strength, light weight, and since it was available cheaply. It holds about 5 days' worth of water (maybe a bit excessive). If the kitchen sink isn't going into the system, the grease trap may not be necessary, but some way of getting out large solids would be.

The dosing siphon is a patented device that stores a set quantity of liquid and then releases it all in one dose. It does this without any moving parts to fail or electricity, by trapping an air bubble between a bell jar and a plumbing trap. This unit is needed so that the effluent is distributed evenly throughout the 40 ft. pile of wood chips, rather than just trickling in at the pipe inlet. It also allows the pile to re-aerate after getting hit with a load of water, so that the decay process will be aerobic, rather than anaerobic.

The switch is a simple cast-in-place concrete chamber about 1 foot in diameter with two outlets. An elbow is fitted over one outlet and turned up to "close" that side of the switch and direct the water to the pile in use. It looks at the moment like each pile will be able to be used for a minimum of two to three years before switching to the second pile. Preliminary digging into the piles has shown that the wood chips are rotting nicely into beautiful black humus, with no odor or gruesomeness.

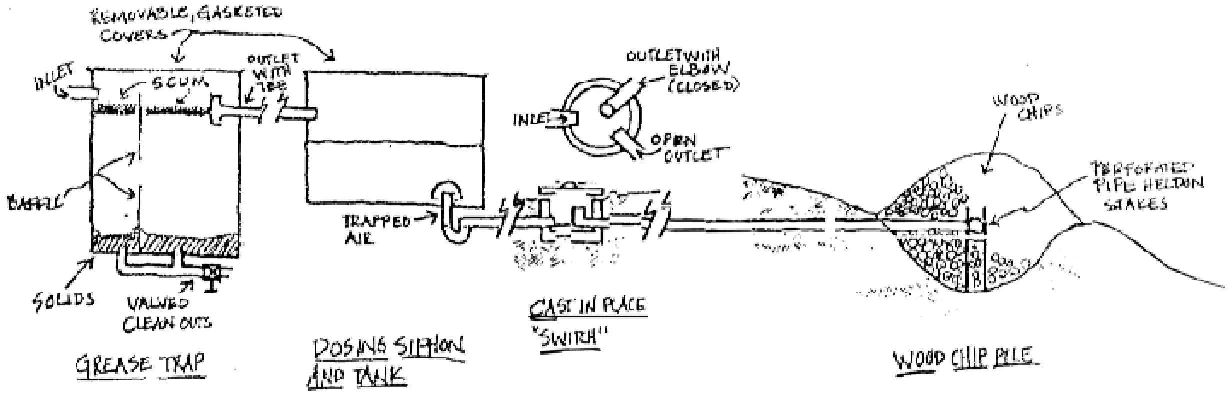
The piles consist of two swales roughed in with a bulldozer when building the house and then finished by hand (lots of boulders here), the diggings piled up on the trench sides as berms (to hold water in), with fiberglass (non-rotting) stakes every few feet to hold the perforated distribution pipe level as the wood chips rot down around it. The distribution pipes turn up and come to the surface at either end of the pile to allow air to flow through. Pile length and width were figured using flow estimates and the state's guidelines for leaching area based on percolation rates in the existing soil. Freezing has not been a problem, as wood chips are excellent insulation!

Wood chips are pretty abundant in these parts, and can sometimes be had by the truckload for free if you catch the road and/or utility company crews at the right time. Doug has his piles located so that the composted wood chips can be simply loaded onto a can and wheeled downhill into his orchards for use as mulch. Sawdust from a lumber mill (also relatively abundant) could also be used.

Doug and I hope to write a Technical Bulletin on this system in the near future, which will provide more of the nitty gritty details on design and construction.

The wood chip system is placed uphill of Doug's nursery so that it gets indirect irrigation with greywater, albeit filtered through chips/sawdust and the ground. Root invasion of the pile by planting on the berms would have to be dealt with by more frequent alternation and emptying of the piles with simultaneous root pruning, and/or by using only annuals near the piles.

One possible change is to put a second set of perforated pipes under the pile to collect the filtered effluent and direct it to a storage for later use as irrigation water. Bacteria/viruses/etc. are the biggest threat on this score, and I don't know how much chip distance is needed to filter them out to a safe level (they say four feet of sand is sufficient for combined wastewater). Making sure that there is a minimum of two to three feet of chips between the pipes at all times should help ensure decent effluent renovation, but more would obviously be better. In addition, pathogen levels in greywater are usually very low, the most danger coming from diaper washings and such, since live polio vaccine viruses and other stuff can get in there. If this is a concern, then it is best to let the effluent leach into the ground, where soil particles and microbes are likely to bind and attack the pathogens before they can do any harm. Pathogens are another reason to let the pile rest after switching off and before digging in. It is important to note that the amount of water coming out of such a system is



likely to be low, due to low flow rates (for a single household, at least), evaporation from the pile and inefficiency of such a collection system unless there is a clay or other impermeable barrier under the pipe to ensure efficient collection.

I have been investigating and researching household wastewater disposal systems for a number of years, looking for systems that can work in a permaculture context. Having convinced myself of the attractiveness and usefulness of composting toilets, this article will focus on treatment of greywater (everything except toilet waste and household or other hazardous wastes, i.e., wastewaters from sinks, tubs, washing machines, even dishwashers, and sometimes including urinals). Presented here are brief summaries of some of the systems I have encountered in my search, including wood chip composting, greenhouse, and constructed wetland greywater systems. I will also briefly discuss intermittent sand filters.

Please note that these descriptions are very brief, and that there are many details left out that can make the system work or not work in a safe manner. I strongly recommend a thorough investigation into local codes and regulations, and getting a good handle on the parameters and risks so you can design, build, and use a safe system. If you want to build one of these based on what is here, you do so at your own risk!

Greenhouse greywater

The greenhouse greywater system was almost made famous by the Clivus Multrum folks in years past as they bravely attempted to break down America's blind barriers to humane treatment of our fecal and other household wastes. I have seen two versions of this concept, one in Abby Rockefeller's place here in NH (over 10 years old), and the other a more down-home system in Concord, MA. The system is simple in concept, but I feel has some problems, which I will discuss later. The basic idea is that the greywater goes through an initial filtration before being pumped to the greenhouse in doses. The greenhouse soils act as the effluent renovation medium, while the greenhouse plants take up some of the nutrients and water (Sketch 2). Such a system could be rigged up for irrigating outdoors in a warm climate, but in cold climates, the greenhouse is used so as to get year-round operation. In effect, the system is a sand filter with plants growing in it. However, read on for the downside.

A screen, a series of successively smaller rock sizes, usually accomplishes the first filtration and then maybe some sand. Clivus Multrum has a rock filter/pump unit combo they sell/sold for the initial filtration, but the folks in Concord, MA, just used an old oak barrel, with a sump pump in the bottom, filled with stone of varying size ranges. Mainly this filter is just to remove solids so they don't clog the pump or the tiny holes in the distribution lines, and it does require a modicum of maintenance to prevent filter clogging.

The filtered effluent is pumped to the greenhouse and distributed through 1" plastic pipe with little holes drilled in it. If you want to get fancy, you can use two pipes, one inside the other, the inside one with tiny holes drilled in it all facing up, and the outer one slitted along the bottom to distribute the flow more evenly and make it harder for plant roots to get in and clog the pipes. It seems to me either way would work. In any case, this pipe is buried 4-6" deep in the greenhouse beds.

In Ms. Rockefeller's case, the greenhouse beds were not earth-connected and were about 3½-4' deep, with the top 6-8" as topsoil and the rest coarse sand. The bottoms of the beds were concrete, with collector pipes sloped to run the excess effluent into a sediment trap, then to a septic tank and leach field (the State of New Hampshire is very paranoid). In Concord, the beds were earth-covered, and they saved all the expense of the extra stuff, except a lot of legwork to get state approval.

I have seen no guidelines for leaching area requirements for such a system. Rockefeller's system served a huge house, though what fixtures actually contributed to the system was unclear, (the initial filter was large), and the house was not a full time residence. The Concord system was about the same size greenhouse (± 125 sq.ft. of beds), but served a three-person household with two baths and a washer, but not the kitchen. I expect that percolation rates had more to do with the size of the Concord system, since it was earth-connected, whereas the Rockefeller installation had a standard septic system afterwards.

The major problem with this kind of system stems from the salts (mainly from soaps and detergents, but also other things) and especially boron that can build up in the soil from continuous greywater application in one spot, especially in a greenhouse where temperatures can go high and add to the evapotranspiration rate quite radically. Some of this, especially the boron, can be avoided through use of soaps rather than modem detergents and the avoidance of anything containing boron or borax. Bleaches are also hard on plants. Neither of the greenhouse systems I saw were in use for growing plants when I saw them (why I don't know), but they had both had a fair amount of use as greywater disposal systems, and the soils didn't look salty. No one had any test results for salts or pH in their greenhouse soils to allay my fears, but they hadn't had any problems with their plants either, which is somewhat of a surprise.

The second problem, for me, at least, is the use of a pump in the system, which requires electricity. Pumping water into the house is bad enough, but to have to pump it at the other end really gets my goat! In order to use gravity and a dosing siphon, one would have to get an adequate height difference (which can be difficult in some cases, especially with attached greenhouses) and use bigger pipe, which would end up hogging more space in the greenhouse bed, which is usually at a premium and is expensive to build, to boot.

For a system of this type, it is important to have some sort of alternative system for the greywater, in case someone gets typhoid fever, dysentery, or infectious hepatitis, which spread quite readily through greywater, especially when in close contact with food.

Constructed wetlands

The use of wetlands to purify water is millennia old. It is only recently that we humans have come upon the' idea of utilizing wetlands to prevent ourselves from drinking our own waste as tap water. Constructed wetlands are now being designed, built, and used in many areas for treating industrial, municipal, and domestic wastewaters, agricultural and urban runoff, and acid and highly alkaline coal mine seepages.

Described here is a constructed wetland system I designed for my home in NH and spent two years trying to get approval to build, to no avail (I am hoping to get approval and build in 1990). Much of what is presented is untried for treating greywater, especially in a cold climate, though the design is derived from extensive literature research, visits to municipal scale installations and discussions with leading researchers in the field. If you want a copy of my design, some design guidelines for household systems and other information, send $12, and you'll get a packet in return.

First of all, let me warn people against using natural wetlands for wastewater treatment, for several reasons: I) the surface and subsurface flow hydraulics are much more difficult to figure out in situ, so that design and monitoring become sketchy, and safe and sanitary operation is much harder to assure; 2) the continental US has already lost almost 60% of its wetlands since colonization, so why run the risk of further disruption, and why not rebuild? 3) natural wetlands are usually in low topographic position, and we would rather purify our wastewater at a higher elevation so that we can use it afterwards; 4) the politics of modifying native wetlands, and especially adding wastewater to them, are VERY touchy.

There are many basic types of constructed wetland systems. These include: surface flow and subsurface flow emergent wetlands, riverine mimics, marsh/pond/meadow or marsh/pond/systems and a number of hybrids of these. This article will describe subsurface flow wetlands. I will review the other systems in a later article.

Subsurface flow wetlands (Sketch 3) are usually constructed with a clay and/or plastic liner (or native soil if impervious enough) and are filled with crushed stone or sand. Into this medium is planted emergent species such as cattails *(Typha latifolia),* bulrush *(Scirpus validus),* reed canary grass *(Phragmites communis),* and/or canna lilies *(Canna flaccida,* a southern species), among others. The water level in these systems is maintained below the surface, thereby eliminating mosquito control problems, reducing evaporative losses, and, in my estimation, improving wintertime performance in cold climate areas.

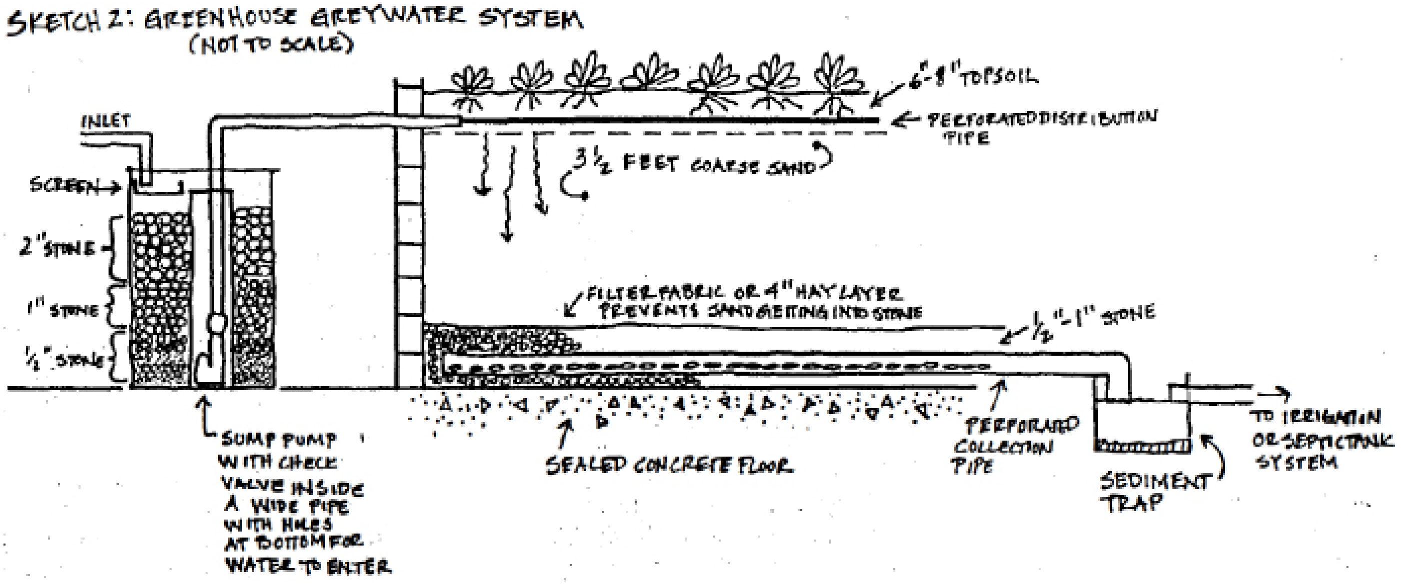
These systems work because of the physical filtration and large surface area for microbial attachment provided by the stone or sand medium and the plant roots, and because these plants in particular are known to supply oxygen not only to their roots, but also to a small region of the soil around their roots. This creates a large amount of edge between aerobic and anaerobic microsites in the root zone of the plants within the bed, which radically increases the rate of pollutant degradation because of microbial diversity and the diffusion of chemicals back and forth across the aerobic-anaerobic edge.

Surface flow wetlands are similar to the above, except that the bed liner of clay or plastic is overlain by some sort of clean fill, and the water flows through the stems and roots of the emergent species above the soil's surface. Here, the plant stems provide physical filtration and bacterial attachment sites, while supplying oxygen to create microsites of aerobic activity within the water column in addition to whatever O2 diffuses through the water surface. These kinds of systems have been used at municipal scale in Canada, but for greywater treatment probably would not work due to the low flow rates and subsequent freezing potential, not to mention increased mosquito control problems.

The greywater system as designed consists of a 50 gallon surge moderator and rock filter, a distribution box, two wetland "cells" in parallel, each with a water level control, and some sort of disposal system—either trenches in the ground if need be, or a pond and/or an irrigation system if not.

The rock filter/surge moderator is basically a large garbage can with a screen at the top and a foot of pea gravel in the bottom. This unit is needed to store surge flows from a bathtub or washing machine so that the slow infiltration of the water into the marshes doesn't end up backing water up into the house plumbing and overflowing at the lowest point. It also removes large solids to help prevent clogging down the line. This kind of filter is used instead of a septic tank to prevent the water from going anaerobic before entering the marshes, which helps with the microbial processes in the marshes. The distribution box that follows splits the flow into two equal amounts for each of the two-wetland cells.

Each medium for the marshes has its advantages and disadvantages in terms of hydraulic conductivity, or how easily the water can flow through, and in terms of treatment efficiency and wastewater renovation. Sand, having a higher surface area, will remove more phosphorus from the water by adsorption



than will stone, which can be good or bad depending on your needs. Sand will also require a wider bed as well as a bigger bed overall because it has a lower hydraulic conductivity and less pore space per volume. For both these reasons, I chose to use stone, since I am interested in using the phosphorus in irrigation and in minimizing the bed size.

This design is also an attempt to explore the limits of wetlands operation in wintertime. Therefore, I chose to place the marshes outdoors and to try various ways of insulating them. The plan calls for use of some foam buried in the ground to create an upwelling of earth heat to the marshes, in combination with thick layers of wood chips and/or straw. In subsequent years after good vegetative growth takes place, simply leaving the plant biomass on top after it dies back may be enough. As a last resort, the marshes were designed to fit inside a standard garden greenhouse structure, which could be built afterwards. In more southern climes, these considerations are null and void, as there are many installations of wetland systems in PA, MD, KY, MS, LA, etc. with fine winter performance.

Water level control is a necessary aspect of both surface and subsurface wetlands systems. There are various means of accomplishing this, the flexible pipe shown being one of them. It is a good idea to lower the water level in subsurface marshes in the late summer and fall to encourage deep root penetration of the beds. Otherwise, water can flow under the plant roots and get less treatment, especially if/when the top of the bed freezes.

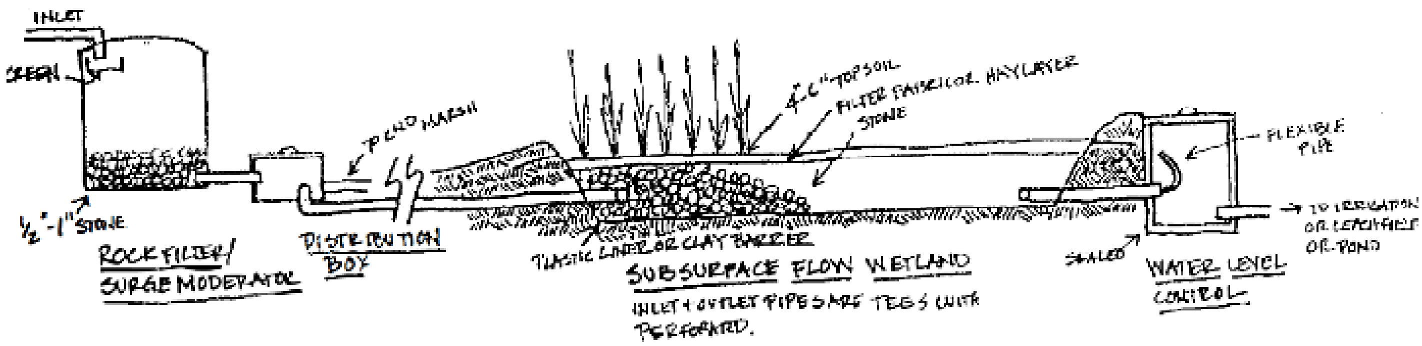
A number of studies have shown adequate removal of pathogens, including viruses, from wastewaters in marsh systems, though more research is needed to confirm these. Nitrogen, suspended solids, and BOD (biochemical oxygen demand) are also removed to levels adequate for surface water discharge in most cases. Some fascinating work has even shown removal of heavy duty toxic organic compounds from industrial wastes! At the same time, the system I designed would be much cheaper to build than conventional septic tank leachfield systems (1/3 the cost at my site), which pollute the groundwater with nitrates anyway, while using fewer resources, and it would actually be beautiful. The biomass generated in the marsh can be used as an essentially seed-free mulch in terrestrial gardens, and cattails and reed canary grass generate edibles for humans. Potential problems with this system include the high evapotranspiration rate of the marsh in summer coinciding with the greatest need for irrigation, the removal of nitrogen from the effluent when we might like that for irrigation, and the potential for inadequate treatment during high rainfall periods. On the first point, this is what storages are for, ponds or otherwise. If nitrogen is desired in the effluent for irrigation purposes, then some other system might be better for your purposes. There is much debate in the constructed wetlands field as to how to deal with high rainfall and other extremes in design, and many conclude that you just have to over-build. My feeling is that if you are only dealing with greywater, the concerns are much smaller. The level of concern is also dependent on the type of disposal system used (trenches, surface water, or irrigation). In general, however, constructed wetlands have a lot of potential for dealing with our wastewater recycling needs.

Intermittent sand filters

Intermittent sand filters have been developed mainly for use with combined wastewater, but are eminently adaptable to greywater treatment. "… the application of pretreated greywaters to intermittent sand filters may be advantageously employed. There is some evidence that higher loading rates and longer filter runs can be achieved with pretreated greywaters" (EPA, 1980, p.116). The Ifo company in Sweden has developed a whole set of components to sell for buried sand filters for greywater treatment in accord with Swedish regulations. These are hard to get in the US, but not impossible.

The advantages of sand filters over some other methods include very clear design guidelines, furnished by the US EPA (EPA, Oct. 1980, *Design Manual: Onsite Wastewater Treatment and Disposal Systems*, EPA 625/1-80-012); and a solid record of research showing good removal of pathogenic organisms (2-4 logs, i.e., reduction to 1/100th -1/10,000th of influent levels), BOD, suspended solids, phosphorus, and nitrogen, producing

SKETCH 3: SUBSURFACE FLOW WETLAND (NOT TO SCALE)



"high quality effluents" (if you are a purist). As an alternative to the conventional, full-sized septic tank/leachfield systems many states require for greywater, they are almost sure to be lower in up-front cost, while providing water useful for irrigation or other purposes.

Sand filters are sized based on various characteristics of the sand itself, as well as flow rates and filter type. They can be built as buried filters, free access filters, or recirculating filters which require pumps. Buried filters arc harder to maintain and replenish, though they don't show above ground, and unless there is a good slope to the land will need a pump for getting the filtered water back to the surface for use. They are loaded at approximately I gpd/sq. ft. or less, depending on media and effluent characteristics. Free access filters have removable covers for regular maintenance, which makes them longer lasting and easier to replenish. They can also be built above ground to facilitate access to the filtered effluent, although the filter must be kept warm in winter if it is to function properly. Free access filters can be loaded at between 5 and 10 gpd/sq. ft., the higher number being more appropriate for greywater as it is less polluted. This type of filter is what I would choose were I to use a sand filter. Pumps break down and cost electricity, so I avoid them when I can, which eliminates recirculating filters from consideration unless there is a need for an extremely high quality effluent. Recirculating filters actually take more space than the simpler free access filter (3-5 gpd/ sq. ft.).

Sand filters must he dosed to function properly. Dosing makes the sand medium, and therefore the biological community, alternate between aerobic and anaerobic conditions. This alternation provides the conditions for optimum elimination of organic compounds and transformation of pollutants into other forms. Many distribution techniques can be used, including ridge and furrow application, drain tile distribution, surface flooding, and spray distribution. Most buried filters use tile distribution, and most free access and recirculating filters use surface flooding in an attempt to insure even spreading of the effluent over the filter surface.

The greatest amount of wastewater renovation takes place in the top 9-12 inches of medium, but most filters are a minimum of 24" deep. Shallow bed depths help keep installation and replenishment cost low, as well as facilitating gravity runoff of filter effluent

I have heard recently that some states are doing away with allowing sand filtration of combined wastewater due to their need for maintenance, which doesn't always take place. Indeed, this is one of the drawbacks of sand filters: they need periodic raking and resting, and once in a longer while, complete replenishment of the sand medium. The required resting means that <u>two</u> must be built, each the standard size, and this takes a fairly large area. Again, the size is reduced when treating only greywater, but two systems can still take up a lot of space.
The other difficulty is figuring out how to make the sand filter itself a multiple function unit. Thermal mass? Use the covers as part of a deck surface? Basement space filler? What makes the most sense to me is to tum it into a wetland and grow plants in it, but then the size increases, as does the evapotranspiration! Alternatively, the greenhouse greywater system described above is similar in some ways, though not as well documented in terms of effluent quality or longevity. Clearly, however, intermittent sand filters can be useful in a number of situations and may be relatively easy to get health department approval for, given the quantity of data available for their design and construction. Δ